The Engineer

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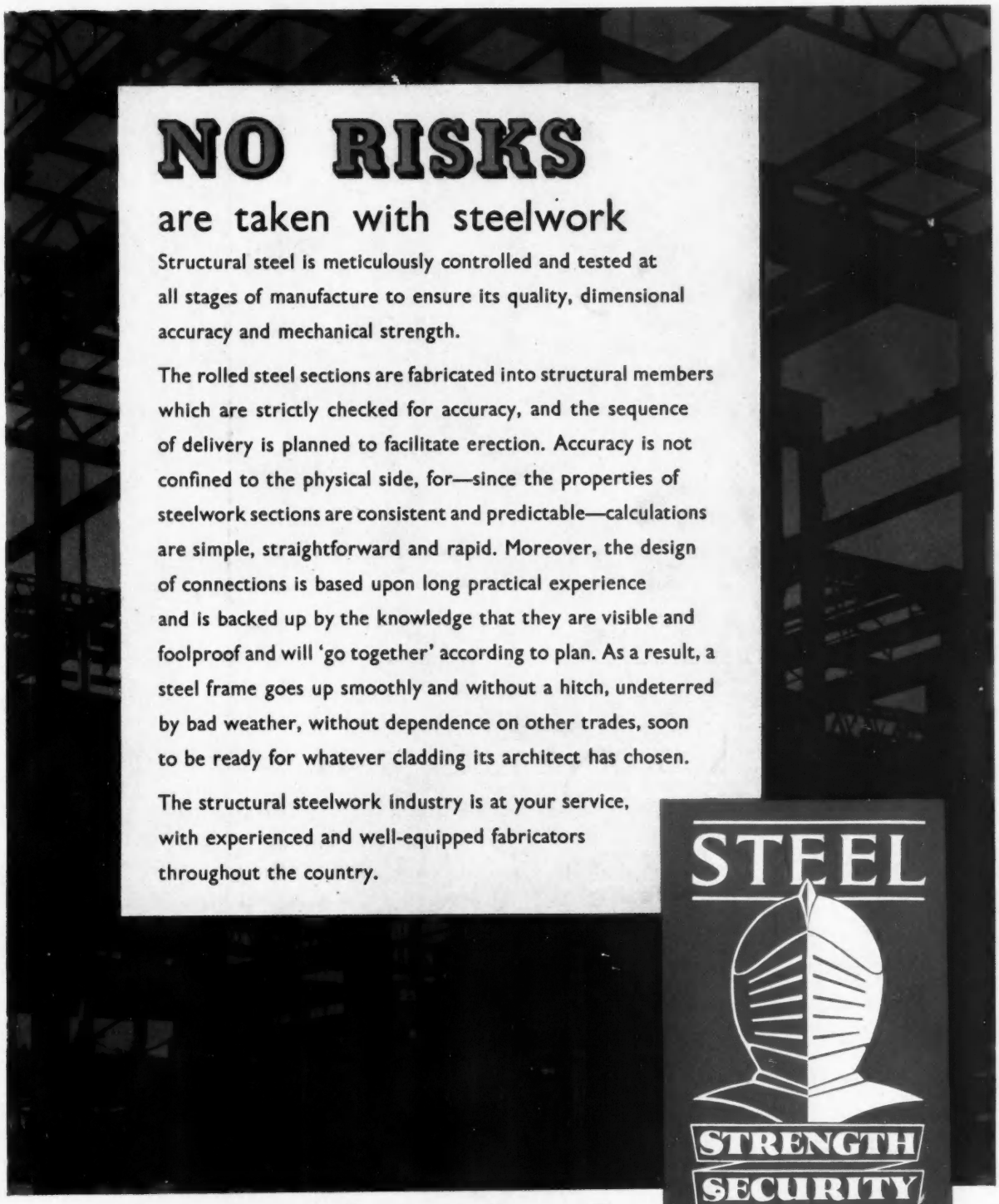

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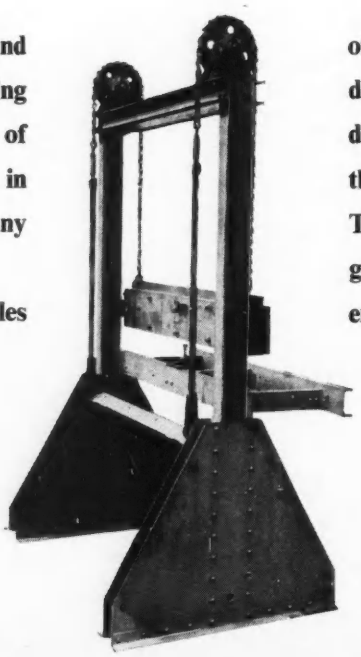

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THE ENGINEER

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WESTERN ENGINEERS AND RUSSIA

At the moment relations between the U.S.S.R. and the West are severely strained by the dreadful events in Hungary and the critical situation in the Middle East. But shocked though we must all feel by recent Russian activities, it is very much to be hoped that neither the West nor Russia will reinstate the Iron Curtain which once shut off from people this side of it any balanced view of Russian technical achievements. On every count it is desirable that the West should know what is happening in Russia and that Russians should have more contact with the West. Politically, Russia and the West are sharply opposed. But despite that cleavage, culturally and above all technically, contact needs to be maintained. For, unwelcome though the fact may be, Russia is in process of becoming one of the greatest industrial nations in the world. Emotional revulsion from her policies should not be allowed to blind engineers here to that fact. There can no longer be doubt about the quality of Russian engineering designers nor of the ability of her manufacturers. Several parties of British engineers have recently visited Russia. Notably in the spring there was a visit of the British Electric Supply Delegation led by Lord Citrine and in October Sir John Hacking led a delegation of hydro-electric engineers to Russia. It is very much to be hoped that present political events will not bring such visits to an end.

Last week Mr. Eccles, who accompanied the British Electric Supply Delegation to Russia, presented a lecture upon the experience before the Institution of Electrical Engineers. It is true of every country that in the main its technical problems will be solved in a manner similar to that adopted by any other. But every country has, in addition, problems individual to itself or, for one reason or another, has a particular urge for forcing the pace of development in certain fields. A large part of the reason, for example, why Britain has gained a lead in the development of nuclear power undoubtedly lies in the perception that solid fuel supplies are likely to run short in the near future. There is in this country, more than elsewhere, a positive incentive to push forward with the development of nuclear power stations. In Russia, similarly, to judge from Mr. Eccles' lecture, climate and geography are causing engineers to pay special attention to certain lines of development. The intense cold of the Russian winter dictates that there shall be combined heat and power stations in the cities despite the fact that fuel has to be carried to them over very long distances. But power needs in excess of the heat loads are tending to be met by the building of condensing power stations near the coalfields and the transmission of energy over long distances to industrial cities. The largest turbo-alternator yet built in Russia is of 150MW capacity, taking steam at 2400 lb per square inch and 1050 deg. Fah. with reheat to 977 deg. Fah.; but designs have been completed for 200MW sets and larger ones are thought possible. The geographical configuration has led to the construction, now under way, of an 800kV d.c. power line between Stalingrad and the Donetz coal basin 300 miles away, and to a plan to standardise upon 1000kV d.c. for long-distance transmission between Siberia and European Russia. Again Russian rivers have such large flows that very great blocks of power can be generated when the rivers are dammed. The hydro-electric developments at Kuybyshev and Stalingrad are both eventually to be equipped with twenty 105MW sets. Such blocks of power cannot be utilised locally even when, as is being done, new industrial towns are built close by. Kuybyshev is already connected to Moscow 505 miles away by a 400kV a.c. line. Plans already

being studied for the development of the Yenisei and Angara rivers, far away east of the Urals, call for eighteen 200MW sets each. In hydro-electric generation the largest sets in service are 105MW at 68·2 r.p.m., but designs are ready for 200MW sets at 250 r.p.m. Maybe with only 37,000MW of installed generating capacity to serve a population four or five times larger than that of this country, with 20,000MW of installed capacity, the Russians may seem still to have far to go. But under the present five-year plan, ending in 1960, it is planned to raise capacity to 75,000MW, as compared with this country's 30,000MW. Some 2500MW will then be generated by nuclear power. The rate of expansion is really remarkable.

All this activity is intensely exciting to electrical engineers. But there is also plenty of interest for others. Recently in our pages we have published accounts of certain Russian civil engineering works whose scale is comparable with that of much more highly publicised American works. Methods of construction are often novel to Western eyes, and the power made available for constructional work remarkable. A figure of 15kW per man for a hydro-electric works under construction by 15,000 men has recently been mentioned. Less seems to be known about the engineering factories in which industrial equipment is built. There is, of course, the well-known automatic piston factory. But is there more ? Mr. Eccles was not very informative ; about a generator works in Leningrad, and transformer, switchgear and cable factories elsewhere he merely remarked " generally speaking the standard of workmanship was good, the tooling varied from very modern to mediocre." Mr. Eccles also mentioned research. There is no need to follow him in detail. For every report from visitors to Russia suggests that its quality is high and that there is no lack of expenditure on equipment. The whole Western world was recently shaken by the figures revealed by Russia showing that more engineers are being trained there per head of population than in any other country in the world. Politically we must feel shocked by recent Russian actions. But technology is not a matter of emotions. It will be a great pity if the impact of recent political events brings a cessation of the visits of Western engineers to Russia.

MIDDLE EASTERN MESS

The whole issue in Egypt and the Middle East is now clouded by emotion. Egypt has been angered by Anglo-French intervention and by Israeli successes in Sinai ; there is resentment and hostility amongst the Arab nations ; shock and surprise elsewhere. The Suez Canal is blocked by no less than thirty-two ships, many of which apparently are canal maintenance vessels. Not one of the oil pipelines to the Mediterranean appears to be in action since the Iraq pipeline has been put out of action in Syria by the destruction of pumping plant ; and Saudi-Arabia has stopped the flow of oil to the Bahrein refinery. There has been an interruption to the flow of oil into Europe, there are insufficient tankers available to make the route round the Cape completely replace that through the Canal ; there is as yet no certainty that American supplies will make up the deficit and freight rates for the carriage of oil are rising sharply. No one benefits by such a situation. There is loss of revenue for the oil producing countries of the Middle East. Egypt benefits no longer from a share in Canal dues. Western Europe either goes short of oil or has to pay dollars for American oil replacing the shortfall from the Middle East. Seen solely through the eyes of engineers the situation is pitiful. Facilities provided by engineers for the benefit of mankind have been put out of action as the consequence of an outburst of nationalism and of mistaken claims to sovereignty. How often engineers have to contend with these emotional conceptions before they can get on with their beneficent works ! Dams cannot be built, water supplies cannot be arranged, irrigation cannot be undertaken, bridges, railways, roads and canals cannot be constructed because of the jealousies, suspicions and mutual distrust of nations, states, counties or parishes. Now because of the existence of similar jealousies, suspicions and distrust a great artery of shipping has needlessly, and as far as we can see, pointlessly been put out of action by the Egyptians, and the flow from one of the sources of the world's fuel has been checked by excessive Syrian and Saudi-Arabian enthusiasm for Arab solidarity.

It is not for us to make judgments about the actions of Egyptian dictators and of British, French, Syrian, Israeli, American and U.N. statesmen. Others are far better fitted than we to discuss the world politics involved. We can only sigh that structures built by engineers for the service of mankind should in a fit of temper have been temporarily broken like children's toys ; we can only wish that amongst the world's statesmen there were more having the approach to technological structures of the engineer, a desire to see them multiplied and efficiently operated so that all men may be enriched, rather than a jealous fear that one nation may be enriched more than another by such structures. We can only remark, as we did when the Egyptians first nationalised the Canal, that claims to sovereignty over such a utility are technologically absurd and certainly not in the world's interest. The control of such a waterway is clearly best placed in the hands of those who most make use of it and most benefit from its existence. For it is more in their interest than of any others that it be properly operated and maintained. Again, taking the situation as it now exists, surely the manner in which the unblocking of the Canal shall be done is not a matter into which narrow nationalism should enter ? The job should be done as quickly as it can be done. The sooner the Canal is reopened the sooner will Egypt as well as Western Europe and much else of the world benefit. To engineers, as to shipowners, furious Egyptian refusals to allow French or British naval forces or contractors to have anything to do with it are just displays of emotionalism that ought to have no part in the solution of an urgent technical problem. If contractors from " neutral " nations can do the work more quickly by all means let them do so. It does not matter who does the work. What does matter is that it should be done as speedily as engineers can do it !

How much will Anglo-French activities in the Middle East have cost this country? And how much additional cost will there be in consequence of the interruption of oil supplies through the Canal and through the pipeline from the Middle East ? Those are questions difficult to answer. The direct cost of military operations has been put by Mr. Macmillan at £35,000,000 to £45,000,000, not a large sum to set against a Budgetary surplus estimated last Spring to reach £460 million. But the true cost will certainly be much higher because, owing to the need to send shipping around the Cape to Australia, the Far East and the oil supply centres of the Middle East, shipping freights are rising fast. Furthermore, so long as supplies of oil from the Middle East are restricted it will be necessary to purchase oil for Western Europe and this country from American sources with a consequent drain on dollar reserves that are none too high to take the strain. In the debate on the address in reply to the Queen's Speech last Monday, Mr. Macmillan said that O.E.E.C., with its American observers, was working on the question of increasing imports of oil into Europe. But the reorganisation of oil supply routes is not something that can be done overnight, and the Government has certainly been right to restrict the supply of oil to major users and to ask pleasure motorists to exercise restraint. Indeed, rationing seems now to be inevitable. How long the restriction upon oil supplies will last depends upon the rapidity with which the Suez Canal can be reopened. The only cheering news within the economic field is that, at nearly £295 million, exports in October reached a record. It is already clear, however, that in next April's Budget the nation will have to consider itself fortunate if the Chancellor, far from being able to reduce taxation, is able to avoid increasing it.

A Seven Day Journal

Royal Society Antarctic Expedition

THE twenty-one members of the main party of the Royal Society Antarctic Expedition for the International Geophysical Year left London yesterday aboard the motorship "Magga Dan." This party, which is led by Colonel Robin Smart, hopes to arrive at Royal Society Base, Halley Bay, at the end of December, and will relieve the ten men of the advance party who sailed from Southampton, early in November, 1955, under the leadership of Surgeon Lieutenant-Commander David Dalgliesh, R.N. The main party will complete the Royal Society Antarctic observatory by erecting further buildings and installing scientific equipment so that the programme of observations being undertaken as part of the International Geophysical Year can begin before July 1, 1957. Most of the members of the party will remain at Halley Bay until the end of the International Geophysical Year in December, 1958, though Colonel Smart will return in January, 1958, when a relief ship is expected to visit the base. The Royal Society's party will work in three groups, namely, a meteorological and geomagnetic group, an ionospheric group, and a radio-astronomy group. The first of these groups will make surface meteorological observations, and will also make measurements of solar radiation and determine the amount of ozone in the atmosphere. The group will construct a non-magnetic hut and make both absolute and relative determinations of the earth's magnetic forces. The ionospheric group is to make studies of the electrified layers of the upper atmosphere including vertical incidence recordings, observations of ionospheric absorption and drift, and measure atmospheric noise. The radio-astronomy group will set up apparatus of the kind which has been operating for some years at the University of Manchester's Jodrell Bank experimental station.

Slipway for Repair of Small Craft at Millwall

LAST week, a slipway and plating shop, for the construction and repair of barges, small tugs, and similar craft, was inaugurated at Millwall, by Admiral Sir William Andrewes. The slipway is claimed to be one of the most up-to-date of its kind on the River Thames ; it will be operated by the Thames Dry Dock and Engineering Company, Ltd., a member of the General Lighterage (Holdings) Group, whose craft will be repaired at the new installation. A disused dry dock—Union Dry Dock—was converted to form the present installation. The old dock was wide enough to form a double slipway and long enough to give a 1 in 76 gradient. Each rail of the two tracks of the slipway is carried on a continuous reinforced concrete beam carried by columns supported on spread footings on the old dock bottom. There is a head of water of 12ft. 6in over the sill on mean neap tides. The plating shop extends for 200ft over the slipway, and there are gantry cranes and a 15-ton double-drum winch installed. The main contractor for this work, who was also responsible for the civil engineering design, was G. Tate and Son, Ltd. The site of the slipway has been used for similar work since 1818 ; the dry dock which the slipway supersedes was 440ft in length and was built in 1898. We understand that it is not the only dry dock on Thames-side which has been filled in in recent years—a contrast to the activity on the north-east coast, for instance, where construction of dry docks is considered an urgent need, but there new installations are, of course, generally much larger, and able to accommodate modern tankers. It is hoped that the slipway at Union Dock will recapture for London some of the building of small vessels which in recent years has been gradually lost to other ports and countries.

The Engineer
100 Years Ago
(NOVEMBER 14, 1856)

"THE LATE MR. RASTRICK"

"John Urpeth Rastrick has departed from amongst us—another knight of the round table of which George Stephenson was the King Arthur. A stout man and a strong, with a will and a purpose, and a brain of one of the old Northern race ; born on the sea coast with the Danish burr in the throat, and going to his work of physical improvement as a Viking to win a promised land. Amidst strife and struggle with Lords and Commons and rival engineers, he won and made the direct line to Brighton, that has given the South Coast as a suburb to London : no small dust this in a man's history. And, as if to show how much better a thing it is to rub than to rust, he has outlived by five years the threescore and ten of average humanity, and double the New York average—a lion of a man to look on ; a Cid of civilisation.

"With his beard so white to see, a man of mark and likelihood, whom people turn round to gaze at as he passed, knowing instinctively that he was a chief and leader. Peace be with him who has lived so long amidst the respect of the modern apostles of civilisation—the brotherhood of railway makers."

"WARSAW WATERWORKS"

"We learn with much pleasure from Warsaw, that the Emperor Alexander has presented Mr. John Head, engineer of the waterworks in that city, with a magnificent gold ring, set with eight diamonds, accompanied by a letter, thanking him for the zeal and energy which he has displayed in the construction of these works. The engines were manufactured by the Messrs. Ransomes and Sims, of Ipswich, and consist of a pair of high pressure, condensing, expansive, beam engines of forty horse power ; their superior construction and excellent finish have elicited the highest encomiums from numerous scientific gentlemen who have inspected them."

Aluminium in Pageantry

THIS year London's centuries-old Lord Mayor's Show had an industrial background and was devoted to one theme, namely, the story of the modern metal—aluminium. The mounting of the pageant was the responsibility of the British Aluminium Company, Ltd., and the design was entrusted to Mr. Ronald Dickens. All facets of the industry found a place in the pageant, including the historical background, symbolised by Eros, and the part played by the aluminium industry in pioneering hydro-electric schemes in the Highlands. Aluminium's contribution to speed in the air, on the water and on land was represented by a scale model of the Fairey "Delta II," Donald Campbell's "Bluebird," and a Jaguar racing car similar to the winner of this year's Le Mans race, having a composite body of magnesium and aluminium alloys. More moderate speed on water was represented by an Albatross marine runabout. In the realm of road transport a design showed the changing fashions, and there then followed a London Transport Executive "Routemaster" bus and a fire-engine, both of aluminium alloy construction. Aluminium as a major shipbuilding material was exemplified by a large-scale model of a ship's superstructure, while another exhibit was designed to emphasise that the metal combines lightness with strength. The value of the material in solving the problems of tropical housing was demonstrated. Aluminium as a structural material was diagrammatically represented.

The City and Guilds Insignia Award

IT will be recalled that, in 1952, the council of the City and Guilds of London Institute established the Insignia Award in Technology. This award is intended to be a mark of distinction for those who have combined sound practical training with an adequate knowledge of the fundamental scientific principles of their subject, and who show a capacity for leadership and administration and for the effective application of their wider knowledge in industry. To fulfil the conditions of the award an applicant must be at least thirty years old, have had a minimum of seven years' suitable industrial progressive experience, and have gained either the Institute's full technological certificate in an appropriate branch of industry, or a suitable alternative. He is required to submit a thesis upon a subject connected with his industry and to appear before an interviewing panel. The Insignia Award in Technology is organised in five broad industrial groups, namely, chemical, constructional, electrical, mechanical and textile. Already sixty-two candidates have qualified in addition to twenty-nine Foundation and Special Awards to selected persons of outstanding technological achievement. The Institute says that candidates are now coming forward not only from the United Kingdom, but from many Commonwealth and other countries overseas.

Air Conditioning in Aircraft

THE ROYAL AERONAUTICAL SOCIETY assembled in strength on Tuesday last to hear a Section Lecture by Dr. E. W. Still, devoted to the pressurisation, cooling and humidity control of aircraft cabins. Weight conservation was a prominent theme in the discourse : when vapour cycle refrigeration was included to deal with the ground cooling of aircraft in the tropics, or of machines cruising at Mach numbers 2 and over, great savings over the use of reciprocating compressors and d.c. electrics were possible. While 400 cycle a.c. showed to advantage, compressed air motors could be even lighter for such purposes as driving circulating fans. Dr. Still developed this theme to show that aircraft in which the auxiliary power unit for engine starting was an air bleed gas turbine could use a markedly lighter air conditioning system, and were independent of ground services for refrigeration as well as for starting. Such units are often kept running throughout the flight, and could be the chosen source of pressurisation at high altitudes. An example of an integrated system was illustrated and described in some detail, and shown to provide a lighter engine starting system than 28V electrics. In the discussion, the acceptability of cooling the cabin by recirculating the atmosphere through the refrigerator, with its great economy in engine bleed air, was argued.

Storm Water Storage Calculations

By B. A. COPAS, M.Sc (Eng.), A.M.I.C.E.

The problem of storage in surface water sewerage systems is tackled from first principles. The article produces a general expression for the maximum volume required, applicable to cases where the duration of the storm is less than the time of concentration of the drainage area, as well as vice versa. Graphs are included, the use of which will materially shorten the work in calculating peak flows and maximum storage required for several rainfall intensity/time curves varying from the "once-a-year" storm to the "once-in-thirty-years" storm.

IN the issues of THE ENGINEER for December 17 and 24, 1954, L. B. Escritt gave an account in outline of the evolution of surface water sewerage theory, and in the latter issue put forward certain formulæ for calculating the volume of storage required to accommodate the difference between a known rate of outgo from a storage reservoir and the inflow due to the storm liable to occur once a year and of such duration and intensity as to call for the maximum storage in the circumstances. Escritt gave his results

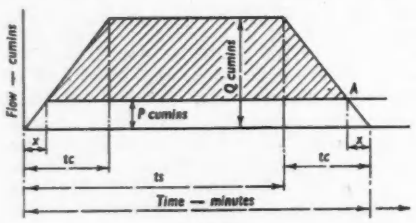

Fig. 1

without the workings on which they were based and admitted to using approximations for the sake of simplicity. As, however, the subject is not only of practical value and of increasing utility, but also of mathematical interest, it is treated more fully hereunder.

THE GENERAL CASE

Consider a catchment area of Ap impermeable acres with a time of concentration of t_c minutes. It is desired to find the storage volume necessary when the outflow rises

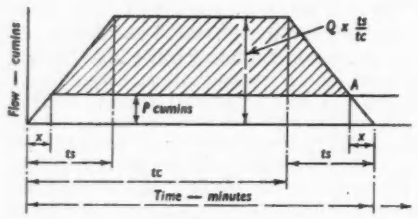

Fig. 2

sharply at the beginning of a storm to P cumins and thereafter remains at this value until the storm has passed.

Let

t_s=duration of storm in minutes.

and

Q=peak flow from catchment area due to storm of duration t_s minutes.

Assuming that the area contributing to the point where storage is required increases at a uniform rate during the time of concentration, the flow cycle will be as shown in Fig. 1. It will be seen that after x minutes from the commencement of the storm the inflow exceeds the outflow and water will continue to pass into storage until point A is reached, which is x minutes before the cessation of inflow. The storage volume is represented by the hatched portion of Fig. 1.

Total volume of inflow up to point A

$$=Qt_s-\frac{xP}{2}.$$

Total volume of outflow up to point A

$$=P(t_s+t_c)-\frac{xP}{2}-\frac{2xP}{2}.$$

Therefore storage volume

C=inflow volume less outflow volume

$$=Qt_s-P(t_s+t_c)+xP.$$

But by similar triangles

$$\frac{x}{P}=\frac{t_c}{Q} \quad \text{and} \quad x=\frac{Pt_c}{Q}.$$

Substituting for x

$$C=Qt_s-P(t_s+t_c)+\frac{P^2t_c}{Q} \quad . \quad . \quad . \quad (1)$$

This is the general expression for storage which may be used for any rainfall intensity/time curve desired, and if no other better method suggests itself the maximum value of C can be found by trial and error insertion of various values of t_s.

Now consider cases where t_s is less than t_c; in other words, rainfall will have ceased before all the area of Ap acres is able to contribute.

As in the previous example, let Q=peak flow from area of Ap acres due to storm of duration t_s, *assuming* the whole area could contribute by the end of time t_s. But the whole area *cannot* contribute by the end of time t_s and peak flow

$$=Q\times\frac{t_s}{t_c}.$$

Proceeding as before, volume of inflow up to point A

$$=\frac{Qt_s}{t_c}\times t_c-\frac{xP}{2},$$

volume of outflow up to point A

$$=P(t_c+t_s)-\frac{3xP}{2}.$$

Therefore

Storage $C=Qt_s-P(t_c+t_s)+xP.$

But

$$\frac{x}{P}=\frac{t_s}{\frac{Qt_s}{t_c}} \text{ or } x=\frac{Pt_c}{Q} \text{ and } C=Qt_s-P(t_c+t_s)+\frac{P^2t_c}{Q}.$$

This expression for C is identical to equation (1) and therefore the one expression is applicable to all values of t_c and t_s.

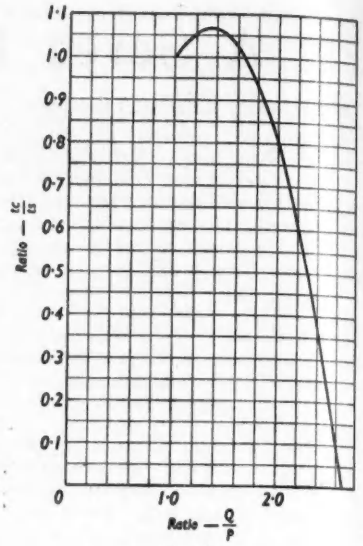

Fig. 3

SPECIAL CASES: "ONCE-A-YEAR" STORMS

It is now proposed to consider the application of this general storage formula to various storm curves of the type

$$R=\frac{k}{t_s^n}$$

where R is rainfall intensity in inches per hour. The form of this expression is most convenient for storage calculations and by selecting appropriate values of k and n, close approximations can be made to

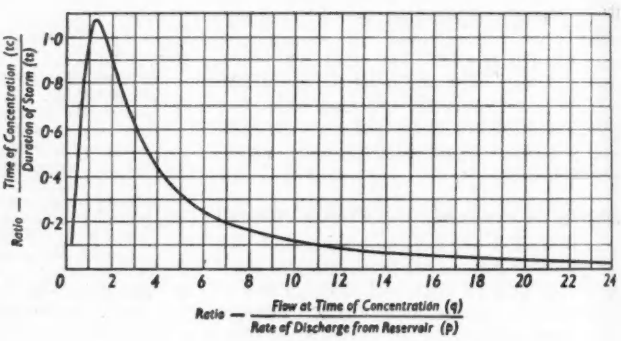
Ratio — Time of Concentration (tc) / Duration of Storm (ts)
Ratio — Flow at Time of Concentration (q) / Rate of Discharge from Reservoir (p)

Fig. 4

Bilham's formula over quite large ranges of t_s. Escritt uses a formula of this kind,

$$R=\frac{5\cdot9}{t_s^{0\cdot625}}$$

as a "once-a-year" storm curve and it is interesting to examine in some detail the general storage formula as applied to this rainfall intensity curve.

As

$$R=\frac{5\cdot9}{t_s^{0\cdot625}}, \quad Q=\frac{5\cdot9\times60\cdot5Ap}{t_s^{0\cdot625}}=\frac{356\cdot95Ap}{t_s^{0\cdot625}}$$

and

$$C=356\cdot95Apt_s^{0\cdot375}-P(t_s+t_c)+\frac{P^2t_ct_s^{0\cdot625}}{356\cdot95Ap}$$

. . . . . (2)

As t_s varies so will C. For maximum value of C differentiate equation (2) with respect to t_s and equate to zero.

$$\frac{dC}{dt_s}=\frac{356\cdot95\times0\cdot375Ap}{t_s^{0\cdot625}}-P+\frac{0\cdot625P^2t_c}{t_s^{0\cdot375}356\cdot95Ap}=0$$

. . . . . (3)

The solution of equation (3) (possibly by trial and error) will give the value of t_s, which, when substituted in equation (2) will give maximum storage.

But

$$Q=\frac{356\cdot95Ap}{t_s^{0\cdot625}}$$

and equation (3) becomes

$$0=\frac{3Q}{8}-P+\frac{5P^2t_c}{8Qt_s}=3Q^2-8PQ+5P^2\frac{t_c}{t_s} \quad . \quad . \quad . \quad . \quad . \quad (4)$$

Solution of this quadratic equation is

$$Q=\frac{8P\pm\sqrt{64P^2-4\times3\times5P^2\frac{t_c}{t_s}}}{2\times3}$$

or

$$\frac{Q}{P}=\frac{8\pm\sqrt{64-60\frac{t_c}{t_s}}}{6} \quad . \quad . \quad . \quad . \quad . \quad (5)$$

This expression shows the relationship between Q/P and t_c/t_s and Table I indicates the values of Q/P for a number of selected values of t_c/t_s. The critical condition is when $64=60\frac{t_c}{t_s}$ or $t_c/t_s=1^1/_{15}$. When t_c/t_s is greater than $1^1/_{15}$ the roots of equation (5) are imaginary. It will be noted that for each value of t_c/t_s between 1·0 and $1^1/_{15}$ there are two admissible values of Q/P.

TABLE I

Ratio t_c/t_s	$\frac{8\pm\sqrt{64-60\frac{t_c}{t_s}}}{6}=\frac{Q}{P}$	Ratio t_c/t_s	$\frac{8\pm\sqrt{64-60\frac{t_c}{t_s}}}{6}=\frac{Q}{P}$
0	2⅔ or 0·0*	1·00	1⅓ or 1·000
0·1	2·602 or 0·064*	1·01	1·6406 or 1·026
0·2	2·535 or 0·131*	1·02	1·6122 or 1·054
0·3	2·464 or 0·203*	1·03	1·5805 or 1·0861
0·4	2·387 or 0·280*	1·04	1·5441 or 1·1225
0·5	2·300 or 0·360*	1·05	1·5000 or 1·1666
0·6	2·215 or 0·451*	1·06	1·4387 or 1·2279
0·7	2·110 or 0·551*	1·065	1·3860 or 1·2806
0·8	2·000 or 0·667*	$1^1/_{15}$	1⅓ or 1⅓
0·9	1·860 or 0·806*	—	—

* These values are inadmissible as the sense of the problem requires Q to be not less than P.

Fig. 3 shows the contents of Table I in graphical form.

Although interesting, the relationship between t_c/t_s and Q/P does not help in finding the maximum value of C, for the reason that every different value of t_s causes a corresponding alteration in Q.

Let q=the peak flow from area Ap acres *at its time of concentration* t_c. (This, after all, is a quantity which will invariably be known before storage calculations are commenced.)

$$q=\frac{356\cdot95Ap}{t_c^{0\cdot625}} \text{ or } 356\cdot95Ap=qt_c^{0\cdot625}.$$

Equation (3) is :

$$0=\frac{356\cdot95\times0\cdot375Ap}{t_s^{0\cdot625}}-P+\frac{0\cdot625P^2t_c}{t_s^{0\cdot375}356\cdot95Ap}.$$

Substituting $qt_c^{0\cdot625}$ for $356\cdot95\,Ap$

$$0=\frac{0\cdot375qt_c^{0\cdot625}}{t_s^{0\cdot625}}-P+\frac{0\cdot625P^2t_c}{t_s^{0\cdot375}qt_c^{0\cdot625}}.$$

$$0=3q^2\left(\frac{t_c}{t_s}\right)^{0\cdot625}-8Pq+5P^2\left(\frac{t_c}{t_s}\right)^{0\cdot375}.$$

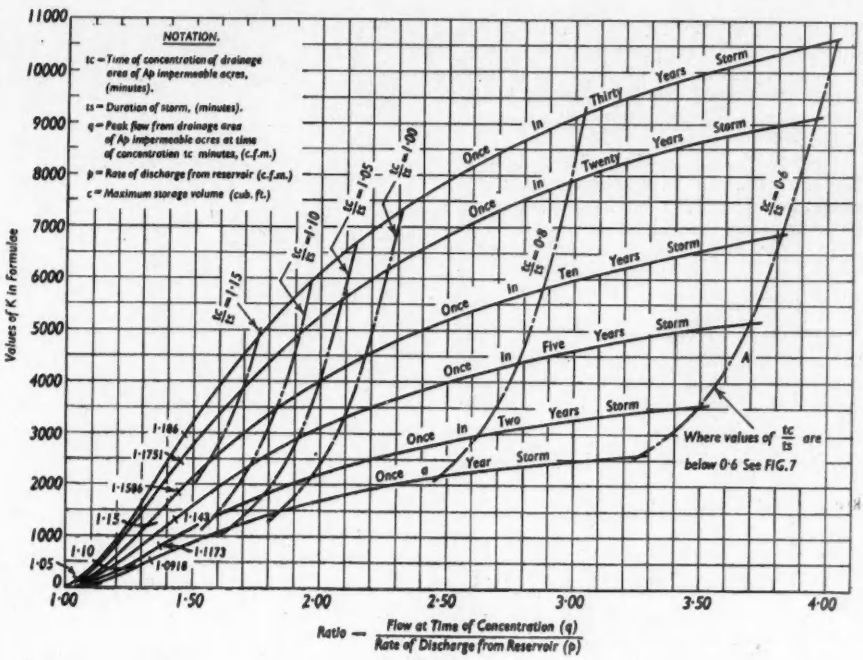
NOTATION.
tc = Time of concentration of drainage area of Ap impermeable acres, (minutes).
ts = Duration of storm, (minutes).
q = Peak flow from drainage area of Ap impermeable acres at time of concentration tc minutes, (c.f.m.)
p = Rate of discharge from reservoir (c.f.m.)
c = Maximum storage volume (cub. ft.)
Values of K in Formulæ
Once in Thirty Years Storm
Once in Twenty Years Storm
Once in Ten Years Storm
Once in Five Years Storm
Once in Two Years Storm
Once in Year Storm
Once a
Where values of tc/ts are below 0·6 See FIG.7
A
Ratio — Flow at Time of Concentration (q) / Rate of Discharge from Reservoir (p)

Fig. 6

Solving this quadratic equation :

$$q=\frac{8P\pm\sqrt{64P^2-3\times5\times4\left(\frac{t_c}{t_s}\right)^{0\cdot625}\left(\frac{t_c}{t_s}\right)^{0\cdot375}P^2}}{2\times3\left(\frac{t_c}{t_s}\right)^{0\cdot625}}$$

and

$$\frac{q}{P}=\frac{8\pm\sqrt{64-60\left(\frac{t_c}{t_s}\right)}}{6\left(\frac{t_c}{t_s}\right)^{0\cdot625}} \quad . \quad . \quad . \quad . \quad (6)$$

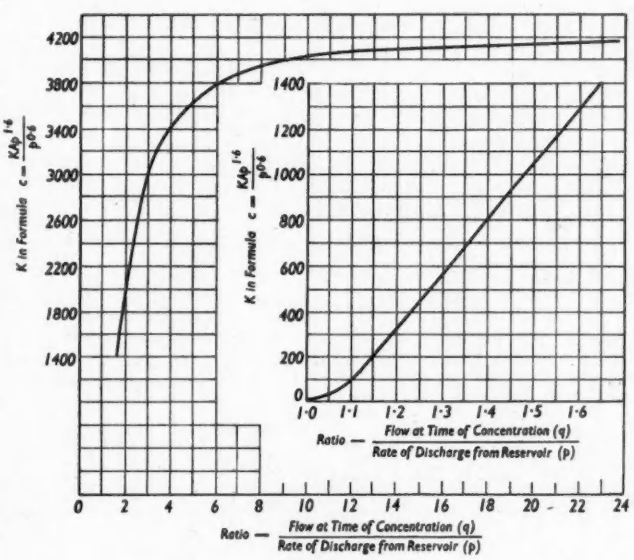

Fig. 5

This expression shows the relationship between q/P and t_c/t_s and Table II indicates the values of q/P for a number of selected values of t_c/t_s. The critical condition is, as before, when $64=60\frac{t_c}{t_s}$ or $t_c/t_s=1^1/_{15}$. Also as before when t_c/t_s is greater than $1^1/_{15}$ the roots of the equation are imaginary, but for each value of t_c/t_s between 1·0 and $1^1/_{15}$ there are two admissible values of q/P.

Fig. 4 shows the contents of Table II in graphical form. The relationship between q/P and t_c/t_s shown thereon suggests a method of finding the maximum value of C without trial and error. In the usual practical case q and P will be known and consequently the ratio q/P will be known. From the graph the corresponding value of t_c/t_s can be read off ; as t_c is known, t_s can be calculated. Substituting for t_s in equation (2) will give the maximum value of C.

TABLE II

$t_c/t_s=\mu$	$\frac{8\pm\sqrt{64-60\frac{t_c}{t_s}}}{6\left(\frac{t_c}{t_s}\right)^{0\cdot625}}=\frac{q}{P}=z$	$t_c/t_s=\mu$	$\frac{8\pm\sqrt{64-60\frac{t_c}{t_s}}}{6\left(\frac{t_c}{t_s}\right)^{0\cdot625}}=\frac{q}{P}=z$
0	—	0·80	2·299 or 0·770*
0·03	23·696 or 0·169*	0·90	1·987 or 0·855*
0·05	17·133 or 0·206*	1·00	1⅓ or 1·000
0·07	13·815 or 0·234*	1·01	1·6305 or 1·0197
0·10	10·976 or 0·270*	1·02	1·592 or 1·042
0·15	8·410 or 0·318*	1·03	1·552 or 1·066
0·20	6·932 or 0·360*	1·04	1·507 or 1·095
0·30	5·228 or 0·430*	1·05	1·455 or 1·132
0·40	4·233 or 0·496*	1·06	1·387 or 1·184
0·50	3·555 or 0·555*	1·065	1·3326 or 1·231
0·60	3·048 or 0·620*	$1^1/_{15}$	1·28062 or 1·28062
0·70	2·643 or 0·690*	—	—

* These values are inadmissible.

The solution of this kind of problem can, however, be further simplified as follows :

Reverting to equation (2)

$$C=356\cdot95Apt_s^{0\cdot375}-P(t_s+t_c)+\frac{P^2t_ct_s^{0\cdot625}}{356\cdot95Ap} \quad . \quad . \quad . \quad . \quad (2)$$

Let

$t_c/t_s=\mu$ when $q/P=z$ or $t_c=\mu t_s$ when $q=Pz$.

But

$$q=\frac{356\cdot95Ap}{t_c^{0\cdot625}} \text{ or } t_c=\frac{(356\cdot95Ap)^{1\cdot6}}{q^{1\cdot6}}$$

$$=\mu t_s=\frac{(356\cdot95Ap)^{1\cdot6}}{P^{1\cdot6}z^{1\cdot6}}$$

therefore

$$t_s=\frac{(356\cdot95Ap)^{1\cdot6}}{P^{1\cdot6}z^{1\cdot6}\mu} \text{ and } t_s^{0\cdot375}=\frac{(356\cdot95Ap)^{0\cdot6}}{P^{0\cdot6}z^{0\cdot6}\mu^{0\cdot375}}$$

$$\text{and } t_s^{0\cdot625}=\frac{(356\cdot95Ap)}{Pz\mu^{0\cdot625}}.$$

Substituting for $t_s^{0\cdot375}$, $t_s^{0\cdot625}$, t_s and t_c in equation (2)

$$C=\frac{(356\cdot95Ap)^{1\cdot6}}{P^{0\cdot6}}\left[\frac{1}{\mu^{0\cdot6}z^{1\cdot6}}\left(z\mu^{0\cdot125}+\frac{1}{z\mu^{0\cdot125}}\right)-\frac{1}{z^{1\cdot6}}\left(1+\frac{1}{\mu}\right)\right]=K\frac{Ap^{1\cdot6}}{P^{0\cdot6}},$$

where K is $356 \cdot 95^{1 \cdot 6}$ times the portion in the square bracket of the previous line.

Using values of μ and the corresponding values of z from Table II, values of K have been calculated, and these are shown in Table III.

Figs. 5 (*a*) and (*b*) show the relationship between q/P and K in graphical form ; two ranges being used to obtain greater accuracy in reading from the graphs.

The largest possible value of K occurs when the time of concentration $t_c=0$, the value then being 4212 (which agrees with Escritt's first formula).

Example.—An area of 100 impermeable acres is drained by an outfall sewer of capacity 4000 cumins. If the time of concentration of the area is twenty minutes, what is the volume of storage required to satisfy the storm curve $R=5 \cdot 9/t_s^{0 \cdot 625}$.

The peak flow from the drainage area

$$q=\frac{356 \cdot 95 \times 100}{(20)^{0 \cdot 625}}=5489 \text{ cumins.}$$

$P=4000$ cumins. Therefore $\frac{q}{P}=\frac{5489}{4000}=1 \cdot 372$.

Reading off from Fig. 5, the value of K corresponding to

$$\frac{q}{P}=1 \cdot 372 \text{ is } 745.$$

$$C=745 \times \left(\frac{100}{4000}\right)^{0 \cdot 6} \times 100=8146 \text{ cubic feet.}$$

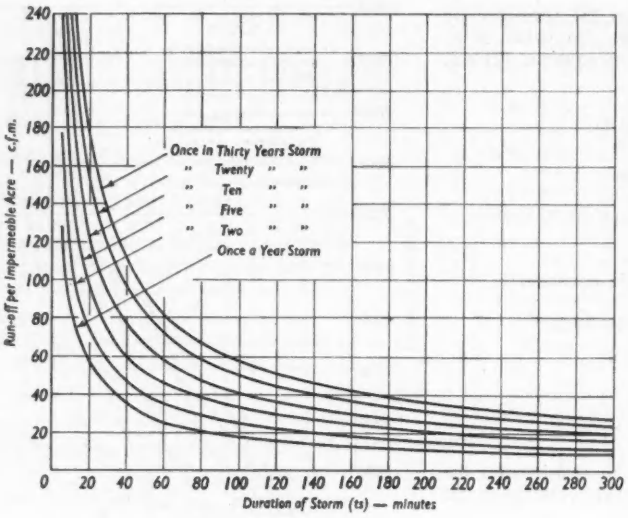
Run-off per Impermeable Acre — c.f.m.
Duration of Storm (ts) — minutes
Once in Thirty Years Storm
" Twenty " "
" Ten " "
" Five " "
" Two " "
Once a Year Storm

Fig. 8

Bilham's Formula

When storage is being considered as an alternative to providing additional capacity in outfall sewers or channels, it must be remembered that storage, if in a confined space, has not the same margin of safety as a new outfall sewer. In other words, once the storage space is full the only margin left before flooding is that possessed by the original outfall sewer in the form of surcharge. For this reason, it is often desired to know the volume of storage required to satisfy storms of greater intensity than are liable to occur once a year.

Bilham's formula probably gives as reliable results as any available at the present time for rainfall intensities liable to occur at various frequencies. This formula, $N=1 \cdot 25t(r+0 \cdot 1)^{-3 \cdot 55}$ (where r=rainfall in inches, t = time in hours and N=number of occurrences in ten years) can be rearranged, using the notation previously adopted in this article, as

$$R=\frac{20 \cdot 163}{N^{0 \cdot 2817} t_s^{0 \cdot 7183}}-\frac{6}{t_s}.$$

This formula, although embracing storms of all frequency of occurrence, is inconvenient for storage calculations and the formulæ shown in Table IV give close approximation to Bilham over the range $t_s=5$ to 600 minutes (and probably longer), the error never being greater than about 4 per cent and generally much less. Using methods similar to those previously explained, basic storage formulæ have been worked out and are also included in Table IV.

Table III

$\mu=t_c/t_s$	$z=q/P$	K	$\mu=t_c/t_s$	$z=q/P$	K	$\mu=t_c/t_s$	$z=q/P$	K
0·03	23·696	4164	0·50	3·555	3261	1·03	1·552	1181
							1·066	47
0·05	17·133	4132	0·60	3·048	3013	1·04	1·507	1077
							1·095	91
0·07	13·815	4099	0·70	2·643	2731	1·05	1·455	950
							1·132	159
0·10	10·976	4049	0·80	2·299	2402	1·06	1·387	782
							1·184	272
0·15	8·410	3963	0·90	1·987	1997	1·065	1·3326	643
							1·231	385
0·20	6·932	3875	1·00	1⅓	1430	1⅛	1·28062	511
				1	Nil			
0·30	5·228	3687	1·01	1·6305	1354	—	—	—
				1·0197	5			
0·40	4·233	3484	1·02	1·592	1270	—	—	—
				1·042	21			

Table IV

Storm frequency of occurrence	Rainfall intensity inches/hour R	Basic storage formula
Once-a-year storm ...	$R=\frac{6 \cdot 180}{t_s^{0 \cdot 646}}$	$C=K\frac{Ap^{1 \cdot 5354}}{P^{0 \cdot 5354}}$
Once - in - two - years storm	$R=\frac{8 \cdot 511}{t_s^{0 \cdot 662}}$	$C=K\frac{Ap^{1 \cdot 5106}}{P^{0 \cdot 5106}}$
Once - in - five - years storm	$R=\frac{12 \cdot 22}{t_s^{0 \cdot 677}}$	$C=K\frac{Ap^{1 \cdot 4771}}{P^{0 \cdot 4771}}$
Once - in - ten - years storm	$R=\frac{15 \cdot 63}{t_s^{0 \cdot 686}}$	$C=K\frac{Ap^{1 \cdot 4599}}{P^{0 \cdot 4599}}$
Once-in-twenty-years storm	$R=\frac{20 \cdot 28}{t_s^{0 \cdot 698}}$	$C=K\frac{Ap^{1 \cdot 4490}}{P^{0 \cdot 4490}}$
Once-in-thirty-years storm	$R=\frac{23 \cdot 44}{t_s^{0 \cdot 699}}$	$C=K\frac{Ap^{1 \cdot 4327}}{P^{0 \cdot 4327}}$

Figs. 6 and 7 show the relationship in two ranges between q/P and K for the six storm curves. The corresponding t_c/t_s curves have also been shown on these graphs so that the duration of storms requiring maximum storage can be estimated if desired.

It is realised that the odd indices in the formulæ given in Table IV are apt to make calculations somewhat tedious and for this reason Fig. 8 has been included so that the run-off per impermeable acre may be read off for any duration of storm between 5 and 300 minutes for each of the six storm curves mentioned.

Example.—Using the same set of conditions as before, a drainage area of 100 impermeable acres is drained by an outfall sewer having a capacity of 4000 cumins. If the time of concentration of the area is twenty minutes, what volume of storage is required for (*a*) a " once-a-year " storm, and (*b*) a " once-in-five-years " storm to prevent surcharge in the outfall sewer.

Case 1 : *Once-a-year Storm.*—From Fig. 8 the flow/acre for time of concentration of 20 minutes=54 cumins. Therefore, peak flow from 100 acres=5400 cumins=q. Rate

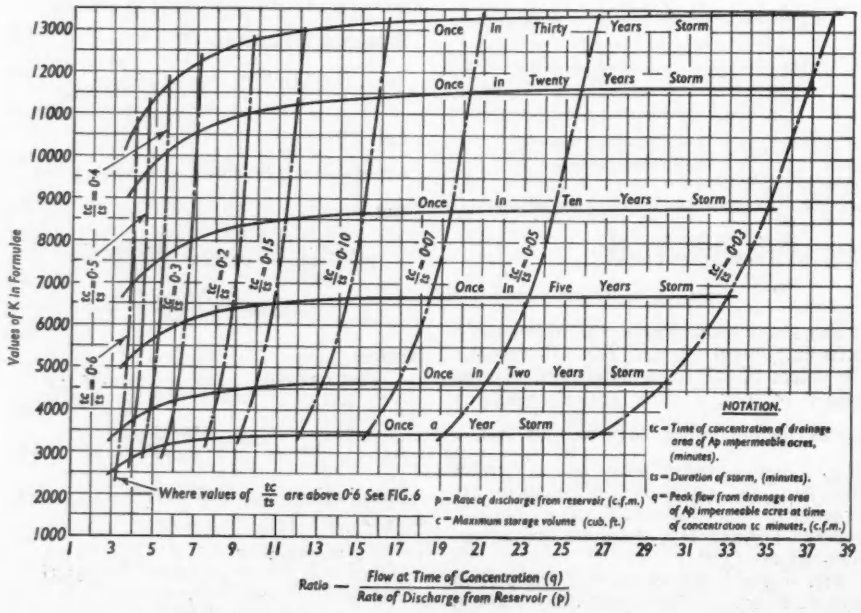
Values of K in Formulae
Once In Thirty Years Storm
Once In Twenty Years Storm
Once In Ten Years Storm
Once In Five Years Storm
Once In Two Years Storm
Once a Year Storm
tc/ts = 0·4
tc/ts = 0·5
tc/ts = 0·6
tc/ts = 0·3
tc/ts = 0·2
tc/ts = 0·15
tc/ts = 0·10
tc/ts = 0·07
tc/ts = 0·05
tc/ts = 0·03
Where values of tc/ts are above 0·6 See FIG. 6
NOTATION.
tc = Time of concentration of drainage area of Ap impermeable acres, (minutes).
ts = Duration of storm, (minutes).
p = Rate of discharge from reservoir (c.f.m.)
q = Peak flow from drainage area of Ap impermeable acres at time of concentration tc minutes, (c.f.m.)
c = Maximum storage volume (cub. ft.)
Ratio — Flow at Time of Concentration (q) / Rate of Discharge from Reservoir (p)

Fig. 7

of outflow P=4000 cumins. Ratio q/P= 5400/4000=1·35.

From Fig. 6, K (when q/P=1·35)=550 and

$$C=550Ap\times\left(\frac{Ap}{P}\right)^{0.5504}$$

$$C=550\times100\times\left(\frac{1}{40}\right)^{0.5504}=7221 \text{ cubic feet.}$$

It will be remembered that in a previous example the "once-a-year" curve $R=5\cdot9/t_s^{0.625}$ gave an answer of 8146 cubic feet to this problem. Apart from slight errors in reading from Figs. 6 and 8 this rather noticeable difference is due to the fact that small differences in rainfall intensity cause comparatively large variations in the volume of storage required. Bilham's formula, for any one value of N, if plotted to logarithmic ordinates and abscissæ, is not a straight line (the departure therefrom being greatest with the "once-a-year" storm, reducing as N reduces, and being almost non-existent with the "once-in-thirty-years" storm), and the values of k and n selected for a formula of the type $R=k/t_s^n$ depend upon the portion of Bilham's curve which the selector considers should be most closely followed. For this particular example, where the time of concentration is twenty minutes, Bilham's formula would give a flow per impermeable acre of 56·0 cumins, whereas Escritt's and the author's formulæ give 54·9 and 54·2 cumins respectively. It is interesting to note that Escritt's formula follows Bilham's "once-a-year" curve more closely than does the author's for times up to about 100 minutes, after which the position is reversed; however, such differences as occur between the three formulæ are of little practical importance.

Case 2: *Once-in-Five-Years Storm.*—

Flow/acre for t_c=20 minutes=97 cumins.

Peak flow=100×97=9700 cumins=q.

$$\frac{q}{P}=\frac{9700}{4000}=2\cdot43.$$

From Fig. 6 K=3900 when q/P=2·43.

$$C=3900\times100\times\left(\frac{100}{4000}\right)^{0.4771}=67{,}100 \text{ cubic feet.}$$

The author makes no apology for concluding with a reminder that the methods and results described have been based on two fundamental assumptions made at the beginning, namely:

(i) That the outflow rises sharply at the beginning of a storm to a certain value and thereafter remains at that value until the storm has passed; and

(ii) That the area contributing to the point where storage is required increases at a uniform rate during the time of concentration giving a flow cycle in accordance with Fig. 1. This flow cycle also includes, of course, the usual assumption that the impermeability factor remains constant during the rainfall.

Assumption (i) is important in keeping the volume required for storage to a minimum. Where this condition cannot be met an average value of outflow during the storm of duration requiring maximum storage should be used in the calculations. Such average value of outflow will probably vary according to the length of the storm and a little trial and error calculation may be necessary to ensure that the average value used in the storage calculations is, in fact, the proper average applicable to the storm requiring maximum storage.

For drainage systems where assumption (ii) is far from true, it may be advisable to use an area/time diagram to set up flow/time curves for various values of t_s and thus find by trial and error measurements of areas below the curves, which value of t_s requires the greatest storage. Alternatively, it may still be possible to use the appropriate curve on Figs. 5(*a*), 5(*b*), 6 or 7 without appreciable error in the result, if a value of t_c can be selected which would make the straight line area/time diagram (assumption (ii)) follow fairly closely the central part of the rising curve of the actual area/time diagram, whilst at the same time keeping the area below the straight line the same as the area below the actual area/time curve.

Some discretion is obviously required in deciding whether the use of an area/time diagram is necessary bearing in mind on the one hand, the particular characteristics of the drainage area and, on the other, that any calculated figure for storage, based as it is on certain rather broad assumptions regarding impermeability factors, rainfall distribution and intensity, cannot be considered in any way a precise answer to the problem. Furthermore, the shape of the area/time diagram is unimportant when t_s is long compared with t_c.

One-Dimensional Transient Flow in a Pipe with two Gases

By R. S. BENSON, M.Sc. (Eng.), A.M.I.Mech.E., A.M.I.Mar.E.*

Unsteady flow in a pipe containing a stratified column of two or more gases at different temperatures is of interest to engineers in connection with either the exhaust pipes of internal combustion engines or the "Comprex" unit in a gas turbine. In this article a theoretical study is made of the unsteady flow process in a simple system of two gases with different molecular weights and ratio of specific heats. The complex equations are by suitable approximations linearised and a solution is produced analogous to the simple case of a temperature discontinuity, which may be solved by the method of characteristics. A detailed example is given. Arising from the linearised theory, parameters are developed for "dynamic" similarity in transient flow systems of two or more gases, and charts are produced from which a rapid computation of the magnitude of the reflected and transmitted pressure waves at the discontinuity may be made. Finally it is shown that in an internal combustion engine exhaust system the effect of the difference in the ratio of specific heats of the exhaust gas and cold air may influence the pressure wave amplitude by about 5 per cent and the wave velocity by about 30 per cent.

IT is well known that pressure waves are reflected at density discontinuities in a pipe; for example in internal combustion engine exhaust pipes where successive columns of hot gas and cold air pass along the pipe or in the "Comprex" unit in a gas turbine. In the usual treatment of this problem the hot and cold gas columns are considered to be of the same type, i.e. equal molecular weights and ratio of specific heats, and the problem resolves itself into a straight temperature discontinuity problem. It is interesting to consider, however, the effect of density variations due to variation in molecular weight and further to investigate the effect of the ratio of the specific heats. Both of these aspects are present in the examples quoted above due to the products of combustion in the exhaust pipe and the variation in specific heat with temperature.

Theory

(*a*) *Exact Solution.*—Consider two gases θ and φ in a pipe (Fig. 1(*b*)). At the position x where the two columns meet pressure p and velocity u are the same. If a disturbance is propagated along the pipe there will in general be reflected and transmitted waves at the discontinuity. The magnitude of these waves depending on the properties of the respective gases at the time of arrival of the pressure wave.

The problem can be readily examined by the theory of characteristics.

For isentropic flow the pressure and velocity of the disturbance (i.e. pressure wave) can be represented in parametric form by the state equation:

$$\frac{dA}{dU}=\pm\frac{\gamma-1}{2} \quad . \quad . \quad . \quad . \quad (1)$$

where

$$A=\frac{\text{local speed of sound } a}{\text{arbitrary speed of sound } a_A}=\left(\frac{p}{p_A}\right)^{\frac{\gamma-1}{2\gamma}} \quad . \quad . \quad . \quad . \quad . \quad (2)$$

and

$$U=\frac{\text{particle velocity } u}{\text{arbitrary speed of sound } a_A} \quad . \quad . \quad (3)$$

p_A=pressure at which arbitrary speed of sound is selected.

γ=ratio of specific heats.

The corresponding position equations are:

$$\frac{dX}{dZ}=U \quad \text{Path line} \quad . \quad . \quad . \quad . \quad (4)$$

$$\frac{dX}{dZ}=U\mp A \quad \text{Mach lines} \quad . \quad . \quad (5)$$

where

$$X=\frac{x}{L} \quad L=\text{Pipe length} \quad . \quad . \quad (6)$$

$$Z=\frac{a_A t}{L} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (7)$$

and x and t are distance and time co-ordinates.

The pressure relationship in equation (2) only applies within the isentropic field, if the arbitrary speed of sound a_A is not on the isentrope (Fig. 1(*d*)) a modified equation will hold (equation 12). Turning now to the problem under consideration, let suffix θ refer to gas θ, and suffix φ to gas φ. Two state diagrams will be necessary corresponding to the two gas fields (Fig. 1(*c*)); if the same arbitrary reference level, $a_{A\theta}$ in this case, is used only one position diagram need be drawn (Fig. 1(*a*)).

For the state diagrams:

Field θ is represented by

$$\frac{dA_\theta}{dU}=\pm\frac{\gamma_\theta-1}{2}=\pm l \quad . \quad . \quad . \quad . \quad (8)$$

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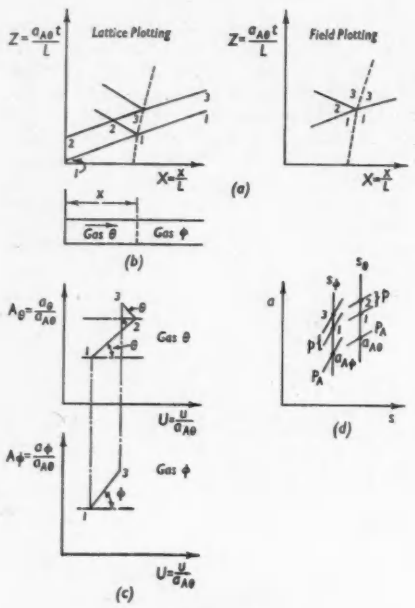


Fig. 1—(a) Position diagrams (b) Position diagram (c) State diagrams (d) Entropy diagram

field ϕ by

$$\frac{dA_\phi}{dU}=\pm\frac{\gamma_\phi-1}{2}=\pm n \quad . \quad . \quad . \quad . \quad (9)$$

and

$$A_\theta=\frac{a_\theta}{a_{A\theta}}=\left(\frac{p_\theta}{p_A}\right)^{1/s} \quad . \quad . \quad . \quad . \quad (11)$$

$$A_\phi=\frac{a_\phi}{a_{A\theta}}=\frac{a_\phi}{a_{A\phi}}\cdot\frac{a_{A\phi}}{a_{A\theta}}=\left(\frac{p_\phi}{p_A}\right)^{1/t}\frac{a_{A\phi}}{a_{A\theta}} \quad . \quad . \quad . \quad . \quad . \quad (12)$$

where

$$s=\frac{2\gamma_\theta}{\gamma_\theta-1}\,;\quad t=\frac{2\gamma_\phi}{\gamma_\phi-1} \quad . \quad . \quad . \quad (10)$$

γ_θ, γ_ϕ are the ratio of the specific heats for gases θ and ϕ respectively,

$a_{A\theta}$, $a_{A\phi}$ are the speeds of sounds on the isentropes θ and ϕ (Fig. 1(*d*)),

$a_{A\theta}$ is the arbitrary reference level.

Consider now a pressure wave 1-2 (Fig. 1(*a*)) and (*c*)) moving to the right; on meeting the discontinuity there will be a reflected wa 2-3 and a transmitted wave 1-3. The magnitude of these waves can be represented by integration of equations (8) and (9) thus :

Wave 1-2 *in Field* θ :

$$A_2-A_1=l(U_2-U_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad (13)$$

whence

$$\left(\frac{U_2}{A_1}\right)_\theta=\left[\frac{1}{l}\left(\frac{A_2}{A_1}-1\right)+\frac{U_1}{A_1}\right]_\theta \quad . \quad . \quad (14)$$

Wave 2-3 *in Field* θ :

$$A_2-A_2=-l(U_3-U_2) \quad . \quad . \quad . \quad . \quad . \quad (15)$$

whence

$$\left(\frac{A_3}{A_1}\right)_\theta=\left(2\frac{A_2}{A_1}-1+\frac{l}{A_1}(U_1-U_3)\right)_\theta \quad . \quad . \quad (16)$$

Wave 1-3 *in Field* ϕ :

$$A_3-A_1=n(U_3-U_1) \quad . \quad . \quad . \quad . \quad . \quad . \quad (17)$$

$$\left(\frac{A_3}{A_1}\right)_\phi=\left(\frac{n}{A_1}(U_3-U_1)+1\right)_\phi \quad . \quad . \quad (18)$$

In terms of pressure equation (16) becomes

$$\left(\frac{A_3}{A_1}\right)_\theta=\left(\frac{p_3}{p_1}\right)^{1/s}=2\left(\frac{A_2}{A_1}\right)_\theta-1-l\left(\frac{U_3-U_1}{A_{1\theta}}\right) \quad (19)$$

equation (18) becomes

$$\left(\frac{A_3}{A_1}\right)_\phi=\left(\frac{p_3}{p_1}\right)^{1/t}=n\frac{A_{1\theta}}{A_{1\phi}}\left(\frac{U_3-U_1}{A_{1\theta}}\right)+1 \quad . \quad . \quad (20)$$

Noting that the pressures and velocity at state points 1 and 3 are the same.

Equation (20) can be re-written in terms of the ratio $\left(\frac{A_3}{A_1}\right)_\theta$, thus

$$\left(\frac{A_3}{A_1}\right)_\theta=\left[\left(\frac{p_3}{p_1}\right)^{1/t}\right]^{t/s}=\left[1+n\left(\frac{a_{1\theta}}{a_{1\phi}}\right)\left(\frac{U_3-U_1}{A_{1\theta}}\right)\right]^{t/s} \quad . \quad . \quad . \quad . \quad . \quad (21)$$

since

$$\frac{A_{1\theta}}{A_{1\phi}}=\frac{a_{1\theta}}{a_{1\phi}}.$$

Substitution of equation (19) into (21) and eliminating $\frac{U_3-U_1}{A_{1\theta}}$ we obtain the following relationship between $\left(\frac{A_3}{A_1}\right)_\theta$ and $\left(\frac{A_3}{A_1}\right)_\theta$

$$\left(\frac{A_3}{A_1}\right)_\theta^{s/t}-\frac{n}{l}\left(\frac{a_{1\theta}}{a_{1\phi}}\right)\left[2\left(\frac{A_2}{A_1}\right)_\theta-1-\left(\frac{A_3}{A_1}\right)_\theta\right]=1 \quad . \quad . \quad . \quad . \quad . \quad (22)$$

Before commencing a calculation it would be necessary to plot the above equation on a separate graph. The characteristic solution requires two state diagrams, within each field the usual plotting techniques† would be used, at the discontinuity equation (22) must be imposed. The solution may, however, be simplified by linearising equation (21), from which it can be shown that one state diagram with two "A" scales can be used and the same technique as for straight temperature discontinuities applied. This method is given below.

(*b*) *Approximate Linearised Solution.*— Expanding equation (21) by the binomial theorem we have

$$\left(\frac{A_3}{A_1}\right)_\theta=1+\frac{t}{s}n\frac{a_{1\theta}}{a_{1\phi}}\left(\frac{U_3-U_1}{A_{1\theta}}\right)+\frac{1}{2}\left(\frac{t}{s}\right)\left(\frac{t}{s}-1\right)\left(\frac{a_{1\theta}}{a_{1\phi}}n\left(\frac{U_3-U_1}{A_{1\theta}}\right)\right)^2+\frac{1}{6}\left(\frac{t}{s}\right)\left(\frac{t}{s}-1\right)\left(\frac{t}{s}-2\right)\left(\frac{a_{1\theta}}{a_{1\phi}}n\left(\frac{U_3-U_1}{A_{1\theta}}\right)\right)^3+ \quad . \quad . \quad . \quad . \quad (23)$$

† Haller, P. (1945): "The Application of a Graphic Method to Some Dynamic Problems in Gases," *Sulzer Technical Review No.* 1, page 6, 1945.

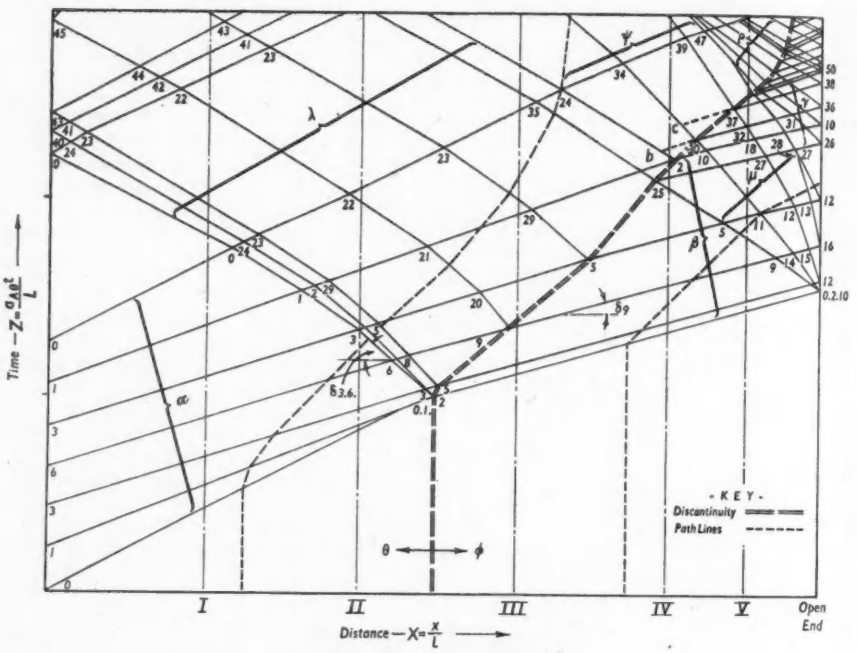


Fig. 2a—Position diagram

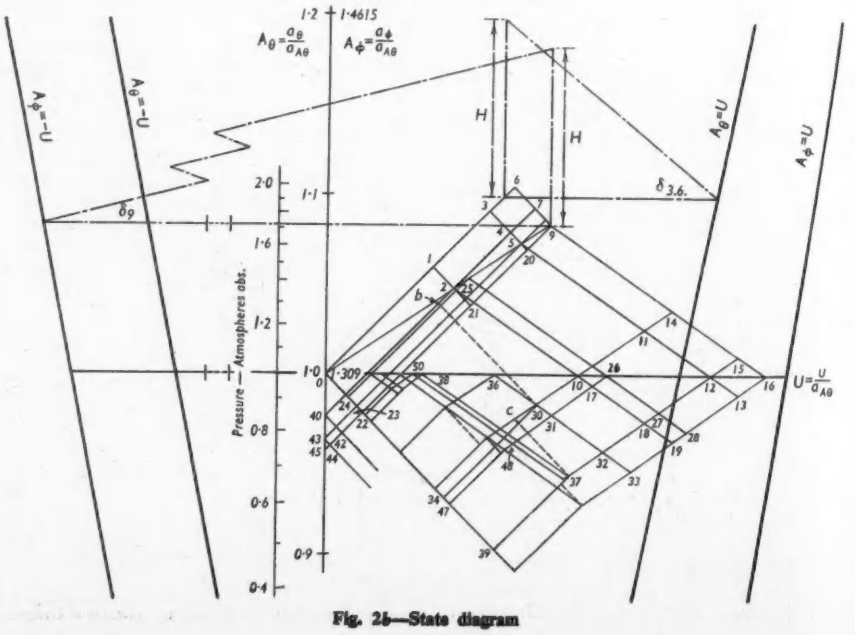


Fig. 2b—State diagram

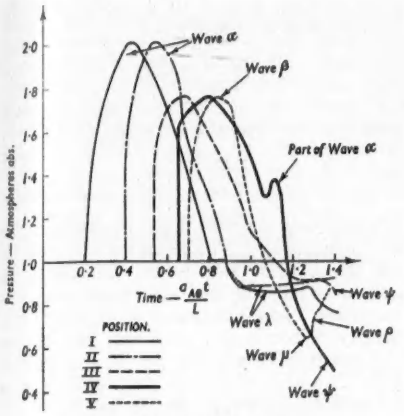


Fig. 2c—Pipe indicator diagrams

This series rapidly converges after the second term for all gases ($\gamma=1\cdot2$ to $1\cdot4$) and the linearised form of equation (21) beomes

$$\left(\frac{A_2}{A_1}\right)_\theta=1+\frac{nt}{s}\cdot\frac{a_{1\theta}}{a_{1\phi}}\left(\frac{U_2-U_1}{A_{1\theta}}\right) \quad . \quad . \quad (24)$$

Eliminating $\left(\frac{U_2-U_1}{A_{1\theta}}\right)$ by means of equation (19) and letting

$$k=\frac{ls}{nt}\cdot\frac{a_{1\phi}}{a_{1\theta}} \quad . \quad . \quad . \quad . \quad . \quad . \quad (24a)$$

we have

$$\left(\frac{A_2}{A_1}\right)_\theta=\frac{2}{1+k}\left(\frac{A_2}{A_1}\right)_\theta-\frac{1-k}{1+k} \quad . \quad . \quad (25)$$

which is the linearised form of equation (22). Now

$$\frac{a_{1\phi}}{a_{1\theta}}=\frac{a_{A\phi}}{a_{A\theta}}\left(\frac{p_1}{p_A}\right)^{\frac{\gamma_\phi-\gamma_\theta}{2\gamma_\theta\cdot\gamma_\phi}} \quad . \quad . \quad (26a)$$

for

$$1\cdot2<\gamma<1\cdot4 \text{ and } 0\cdot5<\frac{p_1}{p_A}<2\cdot0$$

$$\frac{a_{1\phi}}{a_{1\theta}}\simeq\frac{a_{A\phi}}{a_{A\theta}} \quad . \quad . \quad . \quad . \quad (26b)$$

now

$$a=\sqrt{\frac{\gamma GT}{m}}$$

where

G=Universal gas constant.
T=Temperature.
m=Molecular weight.

hence

$$k=\frac{\gamma_\theta}{\gamma_\phi}\cdot\frac{a_{A\phi}}{a_{A\theta}}=\sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}} \quad . \quad . \quad (27)$$

Temperatures $T_{A\phi}$, $T_{A\theta}$ correspond to the isentropic temperatures at the reference pressure p_A. k is a constant and depends on the ratio of specific heats γ, the molecular weight and the initial temperature of the gases at commencement of the wave action.

Substituting equation (25) into equation (16) to eliminate $\frac{A_2}{A_1}$ we have

$$A_{3\theta}=\frac{l}{k}(U_3-U_1)+A_{1\theta} \quad . \quad . \quad . \quad (28)$$

Differentiating along the discontinuity in the θ field we have

$$\left(\frac{dA}{dU}\right)_\theta=\frac{l}{k} \quad . \quad . \quad . \quad . \quad (29)$$

Referring to Fig. 1(c), equations (28) and (29) indicate that the line joinjng the state points (1) and (3) in the θ field has a slope l/k. Now this line in the ϕ field corresponds to the characteristic of the transmitted wave 1-3. Thus the characteristic of the gas in the ϕ field at the discontinuity can be represented by a line joining 1-3 in the θ field. The slope of this line will be l/k and corresponds to

$$\frac{dA_\phi}{dU}=+n \quad . \quad . \quad . \quad . \quad . \quad (9)$$

If $\left[\frac{dA}{dU}\right]_\phi$ =the tangent of the ϕ characteristic on a $A_\theta-U$ state diagram

$$\left[\frac{dA}{dU}\right]_\phi=\frac{l}{k} \quad . \quad . \quad . \quad . \quad . \quad (30)$$

and

$$\frac{\left[\frac{dA}{dU}\right]_\phi}{\left[\frac{dA}{dU}\right]_\theta}=\frac{l}{k}\times\frac{1}{l}=\frac{1}{k} \quad . \quad . \quad (31)$$

Since k is a constant, the lines joining the state points at the discontinuity all have the same slope, hence both the θ and ϕ fields can be represented on the same state diagram.

To obtain the A_θ and A_ϕ scales the velocity parameters U_θ and U_ϕ are equated at the discontinuity. This can be most simply obtained by considering a characteristic passing through the point $A_{1\theta}=1$ $U_1=0$ and verifying the scale relationship for the general case.

For field ϕ integration of equation (9) gives

$$U_{3\phi}=\frac{1}{n}(A_{3\phi}-A_{1\phi}) \quad . \quad . \quad . \quad (32)$$

For field θ the line through the state points at the discontinuity is

$$U_{3\theta}=\frac{k}{l}(A_{3\theta}-1) \quad . \quad . \quad . \quad . \quad . \quad (33)$$

Also

$$U_{3\phi}=U_{3\theta} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (34)$$

$A_{1\theta}=\frac{a_{1\theta}}{a_{A\theta}}=1$, therefore, $a_{1\theta}=a_{A\theta}$ and $p_1=p_A$

$$. \quad . \quad . \quad . \quad . \quad (35)$$

$$A_{1\phi}=\frac{a_{1\phi}}{a_{A\theta}}=\frac{a_{A\phi}}{a_{A\theta}}\left(\frac{p_1}{p_A}\right)^{s/t}=\frac{a_{A\phi}}{a_{A\theta}}=A_{A\phi} \quad . \quad . \quad (36)$$

Eliminating $U_{3\theta}$ and $U_{3\phi}$ we have

$$A_{3\phi}=\frac{nk}{l}A_{3\theta}+\left(1-\frac{s}{t}\right)A_{A\phi} \quad . \quad . \quad . \quad . \quad (37)$$

This equation gives the relationship between A_ϕ and A_θ at the discontinuity and must therefore hold over the whole diagram. Since k is a constant equation (37) is linear and the relationship between A_θ and A_ϕ over the whole diagram is

$$A_\phi=\frac{nk}{l}A_\theta+\left(1-\frac{s}{t}\right)A_{A\phi} \quad . \quad . \quad . \quad . \quad (38)$$

or

$$A_\phi=\frac{s}{t}\cdot\frac{a_{A\phi}}{a_{A\theta}}\cdot A_\theta+\left(1-\frac{s}{t}\right)\frac{a_{A\phi}}{a_{A\theta}} \quad . \quad . \quad (39)$$

at

$$A_\theta=1,\ A_\phi=\frac{a_{A\phi}}{a_{A\theta}},\ U=0,$$

and the scale relationship is

$$\frac{[A_\phi]}{[A_\theta]}=\frac{s}{t}\cdot\frac{a_{A\phi}}{a_{A\theta}} \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad . \quad (40)$$

where $[A_\phi]$, $[A_\theta]$ represent the number of units per inch A_ϕ, A_θ respectively.

Summarising therefore the state either side of the discontinuity may be represented on one state diagram providing

(*a*) $\frac{[A_\phi]}{[A_\theta]}=\frac{s}{t}\cdot\frac{a_{A\phi}}{a_{A\theta}}=k\cdot\frac{\gamma_\phi-1}{\gamma_\theta-1}$ . . . . (40)

(*b*) A_ϕ at ($U=0$, $A_\theta=1$) is $\frac{a_{A\phi}}{a_{A\theta}}$ . . . (41)

(*c*) $\frac{\tan\theta}{\tan\phi}=k=\frac{\gamma_\theta a_{A\phi}}{\gamma_\phi a_{A\theta}}=\sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}}$ . . (42)

where tan θ and tan ϕ are the slopes of the state characteristics in θ and ϕ fields respectively.

The scale relationship equations (38) and (39) were derived by considering a characteristic through the point $A_{1\theta}=1$, $U=0$. For the general case equation (37) beomes

$$A_{3\phi}=\frac{nk}{l}A_{3\theta}-\frac{nk}{l}A_{1\theta}+A_{1\phi} \quad . \quad (43)$$

Substituting for $A_{3\theta}$, $A_{1\theta}$, by using the scale

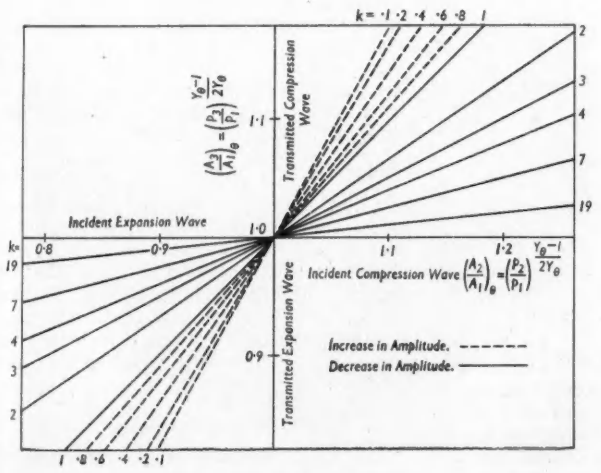


Fig. 3

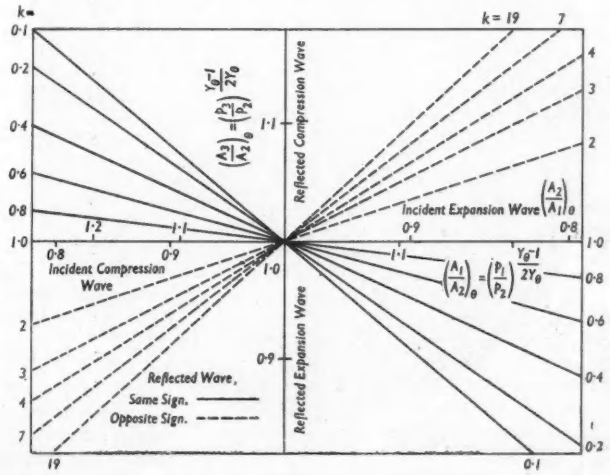


Fig. 4

relationship equation (39) reduces (43) to an identity.

In the previous treatment k was assumed to be constant and hence the loci of the state points at the discontinuity in the θ field all have the same slope.

If the correct value of k given by equation (24*a*) is used the slopes of the loci will not be the same. For example, for a simple pressure wave the slopes will increase with pressure if $\gamma_\theta < \gamma_\phi$ and decrease if $\gamma_\phi < \gamma_\theta$. If one state diagram is used the characteristics will be curved. This may be somewhat complex and it would be simpler to plot two state diagrams, the discontinuity being treated as a physical boundary. The boundary curve in θ field will be given by equation (37) allowing for the variation in k.

The above treatment has been concerned with a wave moving to the right. Exactly the same equations are developed for a wave moving to the left, and the same methods can be used without additional work.

It is interesting to note that when the ratios of the specific heats are the same equations (40) and (42) become the well-known equations for temperature discontinuities.

Application of Linearised Theory

A simple example will now be given to illustrate the above theory.

Two gases θ and ϕ with ratio of specific heats $\gamma_\theta = 1{\cdot}4$ $\gamma_\phi = 1{\cdot}2$, molecular weights $m_\theta = 50$, $m_\phi = 25$ are initially at rest in a pipe. At the discontinuity which is situated mid-length in the pipe the pressure and temperature are equal and $a_{A\theta} = 1000$ft/sec. A pressure wave of magnitude $p = 1 + \sin 100t$ atmospheres absolute is propagated into gas θ from the left-hand end of the pipe from time $t = 0$ seconds to time $t = \pi/100$ sec.: the particle velocity at the left-hand end is then maintained at 0ft per second (i.e. closed end). The right-hand end is open to atmosphere.

The resulting wave configuration can be obtained by the method of characteristics. In using the linearised theory the same techniques as developed by Haller† and Jenny‡ for temperature discontinuities may be used, suitably modified to allow for the varying γ. Thus the slopes of the characteristics in the state diagram

$$\frac{\tan\theta}{\tan\phi} = k = 1{\cdot}526 \text{ from equation (42)}$$

and the scale relationship is

$$\frac{[A_\phi]}{[A_\theta]} = 0{\cdot}762 \text{ from equation (40)}$$

further from the value of k,

$$\frac{a_{A\phi}}{a_{A\theta}} = 1{\cdot}309.$$

For the position diagram the slopes of the characteristics may be obtained by Haller's† method the pole height H (Fig. 2 (*b*)) being

$$\frac{[X]}{[U][Z]}$$

where $[X]$, $[U]$, $[Z]$ represent the scales in units per inch. The auxiliary lines $A_\theta = \pm U$ and $A_\phi = \pm U$ are used for the θ and ϕ fields, the same pole height H is used for each field.

The position diagram is given in Fig. 2 (*a*), the state diagram Fig. 2 (*b*) and pressure-time or indicator diagrams in Fig. 2 (*c*). In the state diagram θ characteristics are ± 45 deg., ϕ characteristics $\pm 33{\cdot}2$ deg. The wave points at the discontinuity for wave crossing (25, 2, 30, &c.) are obtained by linear interpolation and are self-explanatory.

The wave action consequent on the propagation of pulse α into gas θ may be readily examined from the position diagram. The initial pulse α on passing through the discontinuity suffers a reduction in amplitude and is transmitted as wave β, at the same time an expansion wave λ returns towards the left-hand end of the pipe causing a partial depression in gas θ at the closed end. The wave β is reflected at the open end as an expansion wave μ, which travels to the left

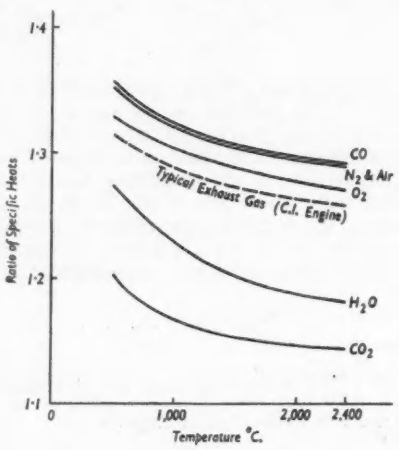


Fig. 5

hand, passing through the discontinuity with increasing magnitude as expansion wave ψ, at the same time an expansion wave ν is reflected from the discontinuity and on further reflection at the open end as a pressure wave returns passing through the discontinuity with increasing pressure.

The theoretical indicator diagrams at several points in the pipe illustrate the effect of the various waves on the pressure-time development. It will be seen from this calculation that the system soon degenerates into a complex wave pattern. It would be useful, however, if a somewhat simpler picture may be obtained. This can be achieved from a study of equation (25)

$$\left(\frac{A_3}{A_1}\right)_\theta = \frac{2}{1+k} \cdot \left(\frac{A_2}{A_1}\right)_\theta - \frac{1-k}{1+k} \quad . \quad . \quad . \quad (25)$$

which gives the relationship between the pressure ratio function of the transmitted wave $\left(\frac{A_3}{A_1}\right)_\theta$ and the incident wave $\left(\frac{A_2}{A_1}\right)_\theta$.

A similar expression for the reflected wave $\left(\frac{A_3}{A_2}\right)_\theta$ may also be obtained,

$$\left(\frac{A_3}{A_2}\right)_\theta = \frac{2}{1+k} - \left(\frac{1-k}{1+k}\right)\left(\frac{A_1}{A_2}\right)_\theta \quad . \quad . \quad . \quad (44)$$

For simple waves with

$$k = \frac{\gamma_\theta}{\gamma_\phi} \cdot \frac{a_{A\phi}}{a_{A\theta}} = \sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}}$$

equations (25) and (44) may be represented by Figs. 3 and 4 respectively. Referring to Fig. 3, giving the relationship between the incident wave $\left(\frac{A_2}{A_1}\right)_\theta$ and the transmitted wave $\left(\frac{A_3}{A_1}\right)_\theta$ it will be seen for $k > 1$ there is a decrease in magnitude for both pressure and expansion waves. Whilst for $k < 1$ there is an increase in magnitude. The reflected waves change sign for $k > 1$ (Fig. 4) and have the same sign for $k < 1$. For $k = 1$ there are no reflected waves. Thus a wave passing from θ to ϕ moves into the equivalent of a rarefied gas if

$$\frac{\gamma_\theta m_\theta}{T_{A\theta}} > \frac{\gamma_\phi m_\phi}{T_{A\phi}}$$

into the equivalent of a dense gas if

$$\frac{\gamma_\theta m_\theta}{T_{A\theta}} < \frac{\gamma_\phi m_\phi}{T_{A\phi}}.$$

In these cases gas θ is the gas upstream of the discontinuity in the direction of the travel of the wave. For two gases with the same isentropic index at the same initial temperature Figs. 3 and 4 represent wave action at a density discontinuity. For one gas at two temperature levels (i.e. $\gamma_\phi = \gamma_\theta$; $m_\phi = m_\theta$). Figs. 3 and 4 represent wave action at a temperature discontinuity.

The velocity of propagation of the wave point will depend on the local speed of sound and particle velocity. For any system the relationship between the speeds of sound will be

$$\frac{da_\phi}{da_\theta} = \frac{\gamma_\phi - 1}{\gamma_\theta - 1} k = \frac{\gamma_\phi - 1}{\gamma_\theta - 1} \sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}} \quad . \quad (45)$$

For any system of two or more gases the conditions for similar wave action called the "dynamic" similarity conditions may therefore be expressed as

$$\text{I} \quad \sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}} = \text{constant} \quad . \quad . \quad . \quad (46)$$

$$\text{II} \quad \frac{\gamma_\phi - 1}{\gamma_\theta - 1} \sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}} = \text{constant} \quad . \quad (47)$$

Parameter I will satisfy the pressure conditions and parameter II will satisfy the time-distance conditions. By means of these parameters dynamically similar systems may be investigated, for example, the simulation of temperature discontinuities at low temperatures by different gases.

Application of Theory to an Exhaust Pipe of an Internal Combustion Engine

The exhaust pipe of a two-stroke cycle engine or a supercharged four-stroke engine consists of a stratified column of hot gas and cold air. The major constituents of exhaust gas in a compression-ignition engine are CO_2, H_2O, N_2, O_2. The isentropic index γ over the temperature range 500 deg. to 2400 deg. Cent. for these gases is shown in Fig. 5.

For a typical fuel with 60 per cent excess air the isentropic index over the same temperature range is shown on the same figure, together with that of air. The molecular weight of the exhaust gases is only slightly above that for air. Assuming an average value of $\gamma = 1{\cdot}28$ for the hot exhaust gases and $\gamma = 1{\cdot}4$ for cold air, the effect of the variation in γ is about 5 per cent of the value of k and about 30 per cent on the parameter $\frac{\gamma_\phi - 1}{\gamma_\theta - 1} k$. The effect of the variation in γ is to retard the wave speed in the hot gas. It would, therefore, appear that for accurate solutions it would be necessary to allow for γ in the calculation. Since in general allowance would be made for the temperature discontinuities the simple corrections given by equations (40), (41), (42), would not add to the complexity of the problem.

Conclusions

The exact solution of the problem of transient flow in a pipe with two gases requires the plotting of two state diagrams

† Haller, P. (1945): "The Application of a Graphic Method to Some Dynamic Problems in Gases," *Sulzer Technical Review No.* 1, page 6, 1945.

‡ Jenny, E. (1949): "Berechnung und Modellversuche über Druckenwellen Grossen Amplituden in Auspuffeitungen. *Doctor's Thesis Z.T.H.S.*

and one position diagram, the discontinuity being represented by a curve. By linearising the equation representing the boundary conditions at the discontinuity one state diagram with characteristics representing the state of the gas in each field need be drawn, and the same technique for plotting as for temperature discontinuities may be used. Arising from the linearised theory, it can be shown that two parameters represent the conditions for dynamic similarity in transient flow systems with two kinds of gases θ and ϕ; these are

$$\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}} = \text{constant and } \frac{\gamma_\phi - 1}{\gamma_\theta - 1}\sqrt{\frac{\gamma_\theta m_\theta T_{A\phi}}{\gamma_\phi m_\phi T_{A\theta}}} = \text{constant.}$$

The effect of the variation in γ for a hot exhaust gas and cold air in the exhaust pipe is approximately 5 per cent on the slope of the state characteristics and 30 per cent on the scale relationship if the variation in γ is neglected.

Decade Air Condenser

By W. H. F. GRIFFITHS, M.B.E., F.Inst.P., M.I.E.E., S.M.I.R.E.

No. I.

In response to many requests for the simplification of the scaling of variable air condenser standards, the author has devoted much thought to the problem and has finally designed and developed a decade air condenser which may be used with confidence to extend the range of a variable air condenser by one or two decades. In effect, this solution simplifies the problem of scaling by ten or one hundred times respectively and eliminates most sources of scale reading inaccuracy as well as those of erroneous interpretation of reading. This article is devoted entirely to the design of the decade of air capacitance and the virtual elimination of all sources of uncertainty of capacitance which might occur. The conventional variable air condenser of the rotating interleaved plane plate type is used as the basis of design and, because of this, ill-defined angular settings of one plate system relative to the other at any decade position must not be allowed to affect the capacitance at that position. Various methods are described of ensuring capacitance stability despite angular uncertainty and the various stages of improvement from the simple variable air condenser are given quantitatively by means of curves of C *and* dC/dθ.

RECENT improvements in the design and construction of the conventional variable air condenser standard have made necessary a very critical examination of the methods of reading the capacitance at any relative angular position of moving and fixed plate systems. There are many kinds of scaling methods, some of which are very accurate but troublesome and others in which accuracy is sacrificed for simplicity of reading. Again, the scaling method associated with a variable air condenser standard is often influenced by the law by which capacitance and scale angle are related.

The scale reading accuracy, of course, must not be permitted to affect the overall accuracy of the condenser to an appreciable extent, but the former is hard to define since it depends so much upon the sight, care and patience of the user and upon the confidence with which interpolation between adjacent scale markings is effected. The time allowed for making a reading of the condenser scale must also have a bearing upon the accuracy of reading and, therefore, it follows that, for a given scale, the reading accuracy to be expected in the laboratory will be better than that in the workshop.

Nowadays, however, in telecommunication production it often happens that extremely accurate measurements of capacitance have to be made in the workshop by semi-skilled operators on large quantities of products—measurements on which little time is afforded for the accurate reading of very finely engraved scales, such as that shown in the illustration of Fig. 1, even if the operator possesses the requisite skill and care to do so.

There are some experienced laboratory workers, on the other hand, who devote much thought and care to the reading of such a scale and undoubtedly achieve a high degree of accuracy. To these, a scale of the fineness shown in the illustration presents no apparent difficulties, but even they occasionally make an erroneous reading (as distinct from an inaccurate one), especially in cases where the value of the subdivisions changes as at 20 or 40 of scale B1. Such errors occur mostly when the user is concentrating more upon his interpretation of the results being obtained than upon the actual operation of reading.

One way of designing an air condenser with a scale which may be read with ease yet without loss of accuracy is that of providing one or two decade dials followed by an ultimate continuously variable dial. Such a design of 1100$\mu\mu F$ maximum capacitance and having two decades would reduce the magnitude of a possible scale reading inaccuracy to one-hundredth of that of an ordinary variable air condenser of equivalent range. The simplicity of the scale shown in Fig. 2 shows well the advantage over that illustrated in Fig. 1—it will be noted that although the scale is engraved in terms of actual capacitance, all divisions are of the same magnitude and a frequent source of erroneous reading is thus eliminated.

But an arrangement of this kind, if assembled from a number of fixed air dielectric condensers of conventional design and associated with switch gear for connecting them in parallel as shown in the diagram of Fig. 3, would prove to be very expensive. Moreover, there would be many objections to the scheme, such as the space occupied, the excessive power factor caused by the

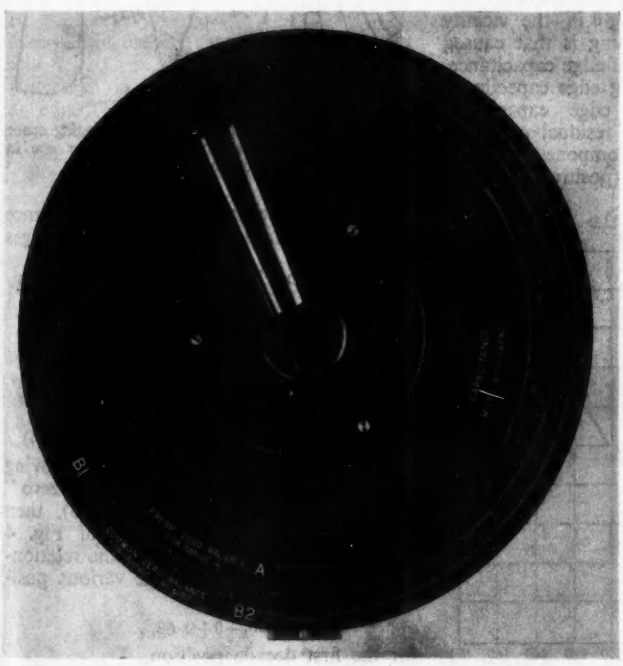


Fig. 1—To illustrate the difficulty of reading the highly accurate scale of a variable air condenser of conventional design

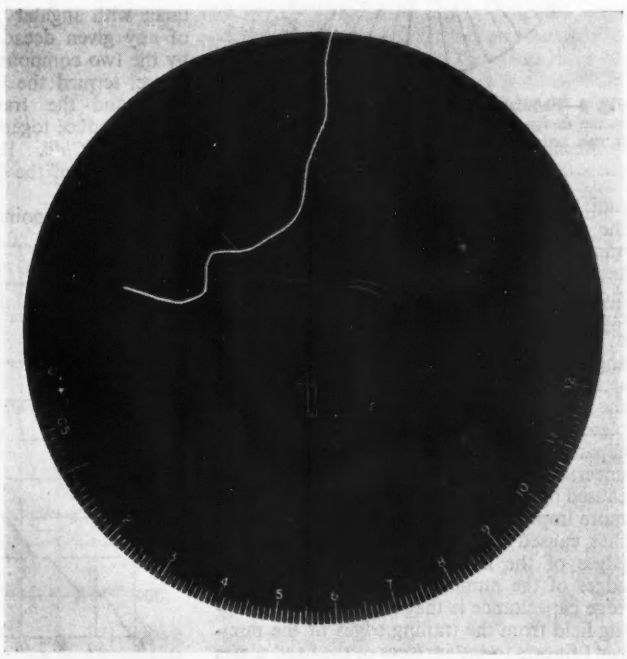


Fig. 2—Illustrating the simplicity of the ultimate scale associated with a decade air condenser

independent solid insulating material needed for the mechanical separation of the plate systems of every fixed condenser to which must be added the inter-contact dielectric losses of the switches themselves. Finally, there is the difficulty of obtaining switch contact resistance so reliably low that it will not contribute appreciably to the losses at the high frequencies at which *air* condenser standards are frequently used.

The author has designed a decade of air capacitance in which the disadvantages enumerated above are avoided. Adjustment of capacitance throughout the decade is obtained without troublesome switchgear and without the slightest augmentation of power factor above that which is present normally in the variable air condenser, the range of which may be extended to ten or even one hundred times its value.

The design is fundamentally that of a variable air condenser having the conventional inter-leaving systems of semi-circular fixed and moving plates, but the latter are fingered radially into a decade of sectors as shown in Fig. 4. The fingers are rotated into the fixed plates to give the required capacitance increments, the relative position of the fixed and moving plate systems for each increment being determined by a "click" device. This click ensures that the

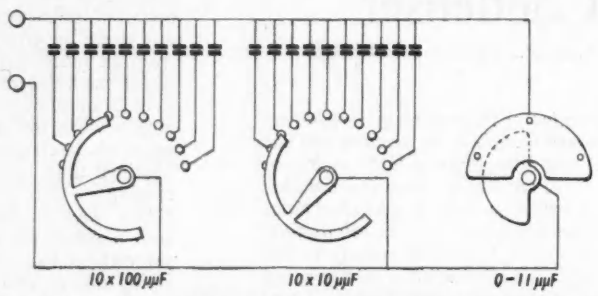


Fig. 3—Diagram of two decades of fixed air capacitances (with their attendant means for switching), together with an ultimate continuously variable air condenser

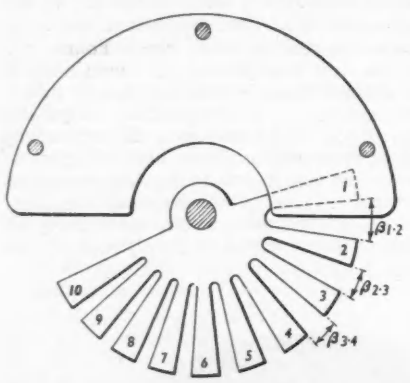


Fig. 4—Showing the shape of moving plate required in the design of the decade air condenser described in this article. The moving plates are shown set at the first position of the decade

radial edges of the fixed plates (into which the moving plates are entering) always approximately bisect* the angular gap between adjacent fingers. For example, the moving plate system of Fig. 4 is shown set correctly for the first capacitance increment of the decade and it is seen that a small angular movement from this "clicked" setting produces no corresponding change in the active (interleaved) area between the two plate systems. Thus, the only changes of capacitance consequent upon small angular uncertainties of click positioning are those caused by changes of edge capacitances. The more important of these edge capacitances is that caused by the field between the radial edges of the fixed plates and the leading edges of the number 2 fingers. The other edge capacitance is that caused by the fringing field from the trailing edges of the number 1 fingers to the surfaces of the fixed plates which embrace them. The reason for the variation of the leading edge capacitance with small angular movement of moving plates is obvious because of the changing effective field length.

The fringing field from the trailing edges of the number 1 fingers is limited by the proximity of the radial edges of the fixed plates and the extent of the limitation varies with small angular movement of the moving plate. Thus a reason for the variation of the trailing edge capacitance is provided.

These edge capacitances may be made very small relative to the main "interleaved" capacitance, by appropriately proportioning the angular spaces between the fingers. Thus, by examining more closely the moving plates of Fig. 4, it will be seen that the finger separation is greatest between the first and second positions of the decade and gradually diminishes throughout the decade as the capacitance increases. In this way the value of $dC/d\theta$ caused by edge capacitance at any decade position is arranged to be roughly proportional to the capacitance at that position. The capacitance curve for the whole decade of a condenser such as that shown in Fig. 4 is given in Fig. 5, and it is the designer's aim, of course, to reduce $dC/d\theta$ at each decade position to a negligible value and to ensure that the decade is "clicked" into position at the exact minima of $dC/d\theta$ so that any angular uncertainty of the mechanical click device will produce only negligible uncertainty of capacitance.

It is seen that the only change in capacitance with angular setting θ in the vicinity of any given decade setting is that caused by the two components of edge capacitance. These, termed the leading edge capacitance $C_{E(L)}$ and the trailing edge capacitance $C_{E(T)}$, produce together a residual minimum value of $dC/d\theta$. Both components of this residual are of the same (positive) algebraic sign.

At the mid-point of the angular space between any adjacent pair of moving plate sectors, it is obvious that the leading edge capacitance $C_{E(L)}$ has much the greater effect upon $dC/d\theta$ and that the effect of the trailing edge capacitance $C_{E(T)}$ upon $dC/d\theta$ is small by comparison.

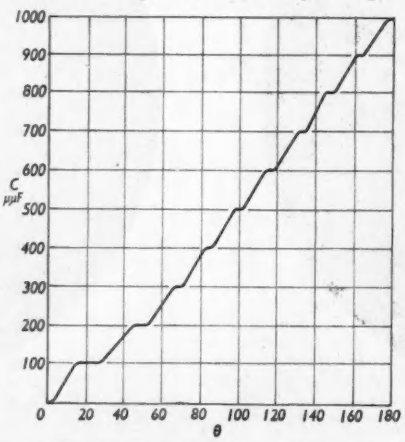


Fig. 5—The complete capacitance curve throughout the whole range of the decade air condenser

The predominating leading edge capacitance $C_{E(L)}$ may be estimated by the following approximate method based upon the assumption that the capacitance between the radial edges of the moving and fixed plates is the same as that between the two complete plane radial surfaces embracing them. This assumption becomes erroneous when the angular separation between the two plate systems is small, more particularly when the dielectric air gaps are large and/or the plates thin. For the angular dimensions and air gap distances of the present problem, however, the approximation is most useful, as will be seen later.

Referring to Fig. 6,

$$G = R\cos\tfrac{1}{2}\alpha,$$
$$D = 2R\sin\tfrac{1}{2}\alpha.$$
$$\delta G = \cos\tfrac{1}{2}\alpha\,\delta R,$$
$$\delta C_{E(L)} = \frac{M\cos\tfrac{1}{2}\alpha\,\delta R}{4\pi(2R\sin\tfrac{1}{2}\alpha)},$$
$$\frac{dC_{E(L)}}{dR} = \frac{M\cos\tfrac{1}{2}\alpha}{8\pi\sin\tfrac{1}{2}\alpha}\cdot\frac{1}{R} \quad . \quad . \quad . \quad . \quad . \quad (1)$$
$$C_{E(L)} = \frac{M}{8\pi}\cot\tfrac{1}{2}\alpha\int_r^{R_m}\frac{1}{R}\cdot dR$$
$$= \left[\frac{M}{8\pi}\cot\tfrac{1}{2}\alpha\,\log_e R + \text{constant}\right]_r^{R_m}$$
$$. \quad . \quad . \quad . \quad . \quad (2)$$

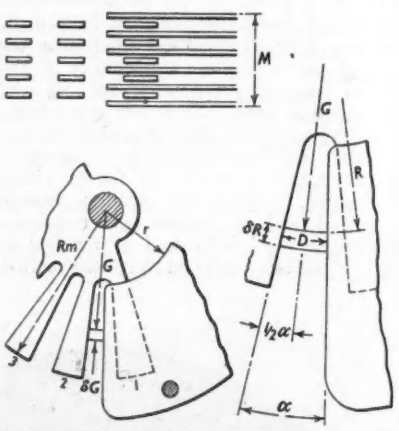


Fig. 6—The dimensioning of the field fringing space between fixed and moving plate edges for use in developing the formula for $C_{E(L)}$

Therefore, the leading edge capacitance $C_{E(L)}$ between moving and fixed plate edges

$$= \frac{M}{8\pi}(\log_e R_m - \log_e r)\cot\tfrac{1}{2}\alpha \text{ in cm units}$$
$$= \frac{M}{7\cdot 2\pi}(\log_e R_m - \log_e r)\cot\tfrac{1}{2}\alpha\ \mu\mu F$$
$$. \quad . \quad . \quad . \quad . \quad (3)$$
$$\frac{dC_{E(L)}}{d\alpha} = -\frac{M}{14\cdot 4\pi}(\log_e R_m - \log_e r)\operatorname{cosec}^2\tfrac{1}{2}\alpha$$
$$. \quad . \quad . \quad . \quad . \quad (4)$$

If θ is the angular movement of the moving plate system from the position of "zero" or residual capacitance (see Fig. 5), then from the angular dimensioning of Fig. 4 it is seen that the following are the relationships between α and θ for the various positions of the decade :—

$$\alpha = \theta_1 - \theta + 0\cdot 6\beta_{1\cdot 2}$$

for the first decade position,

$$\alpha = \theta_2 - \theta + 0\cdot 6\beta_{2\cdot 3}$$

for the second decade position, and so on.

* This is not strictly accurate—the best position will be seen in Fig. 4, the visible portion of the gap being very approximately $0\cdot 6\beta_{1\cdot 2}$.

In these expressions it will be seen that

$$\frac{d\alpha}{d\theta} = -1,$$

and so, although $dC_{E(L)}/d\alpha$ is negative, when relating the edge capacitance to the actual rotation, θ, of the condenser, the sign changes and $dC_{E(L)}/d\theta$ becomes positive, so

$$\frac{dC_{E(L)}}{d\theta} = \frac{dC_{E(L)}}{d\alpha} \times \frac{d\alpha}{d\theta}$$
$$= \frac{M}{14 \cdot 4\pi}(\log_e R_m - \log_e r)\,\mathrm{cosec}^2 \tfrac{1}{2}\alpha \quad . \quad . \quad . \quad . \quad (5)$$

In order to show the extent of the error in expression (3) caused by the approximation to which reference has been made, the curves of Fig. 7 have been plotted for a case where $M = 5$, $R_m = 5 \cdot 7$ and $r = 2 \cdot 54$.

The calculated value of $C_{E(L)}$ (heavy curve) is seen compared with the actual value (light curve) and quite good agreement will be observed over a considerable range of values of α. The actual value was measured by constructing a special variable condenser to the correct dimensions but with angular limitations on both fixed and moving plates,

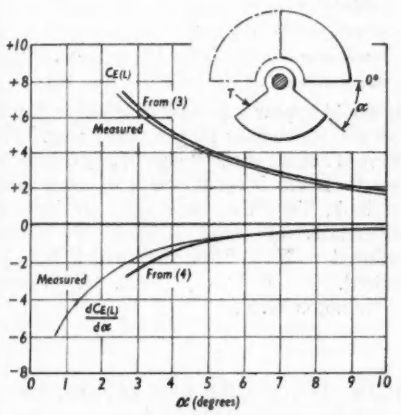


Fig. 7—Curves of "leading" edge capacitance $C_{E(L)}$ plotted from the results of both calculation and actual measurement. The inset drawing shows the method of making the measurements. Corresponding curves of $dC_{E(L)}/d\alpha$ are also given

as shown in the sketch which is included in Fig. 7. These angular limitations were imposed in order to eliminate the complicating edge capacitance to the trailing radial edges T of the moving plates. The corresponding curves of $dC_{E(L)}/d\alpha$ are also given in Fig. 7 and it is seen that even here quite good agreement has been obtained between the results of calculation and experiment.

The following tabulation gives the values of $dC_{E(L)}/d\theta$ for all ten positions of the decade constructed for the values given above and for the plate shape shown in Fig. 4. In the second column are the values computed from expression (5) and these may be compared with those obtained from actual measurements of the completed condenser which are given in the fourth column. In the third column are values more exactly

C ($\mu\mu F$)	$dC_{E(L)}/d\theta$ calculated from (5)	$\Delta C_E/\Delta\theta$ algebraic sum of leading and trailing edge capacitance measurements	$\Delta C/\Delta\theta$ actually measured on a condenser
100	0·4	0·45	0·4
200	0·8	0·75	0·75
300	1·0	1·0	0·8
400	1·3	1·2	1·1
500	1·6	1·5	1·2
600	2·3	2·2	2·1
700	3·0	2·7	2·5
800	3·0	2·7	2·5
900	3·0	2·7	2·5
1000	—	—	0

computed from the independently measured values of $\Delta C/\Delta\theta$ for both the leading and trailing edge capacitances. It is interesting to note that there is very good agreement between the calculated and measured values of $dC/d\theta$.

The calculated value of $dC_{E(L)}/d\theta$ should, of course, be too low at the $100\mu\mu F$ setting

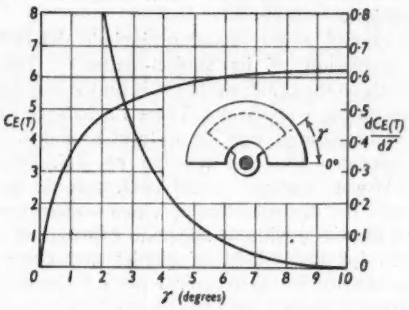


Fig. 8—Curves of "trailing" edge capacitance $C_{E(T)}$ measured under conditions indicated by the inset drawing in which it will be seen that the effects of "leading" edge capacitance are eliminated. The corresponding curve of $dC_{E(T)}/d\gamma$ is also given

because of the additional effect, $dC_{E(T)}/d\theta$, of the trailing edge capacitance which has been neglected in formula (5). On the other hand, the calculated values should become too great at the higher capacitance settings because, although the trailing edge capacitance here is really negligible, the error caused by the approximation used in the development of the formula assumes appreciable proportions. It will be seen that the former tendency to error is scarcely discernible but that the latter tendency is marked.

At the $1000\mu\mu F$ setting $\Delta C/\Delta\theta$ is zero because the moving plates are entirely embraced within the fixed plate system and $dC/d\theta$ caused by the change of edge capacitance of the trailing radial edges of the moving plates is exactly equal in magnitude and opposite in algebraic sign to that caused by the edge capacitance of the leading radial edges provided that the moving plates are symmetrically positioned.

The trailing edge capacitance was measured and plotted as shown in Fig. 8 and it is interesting to add the values of $dC_{E(T)}/d\gamma$

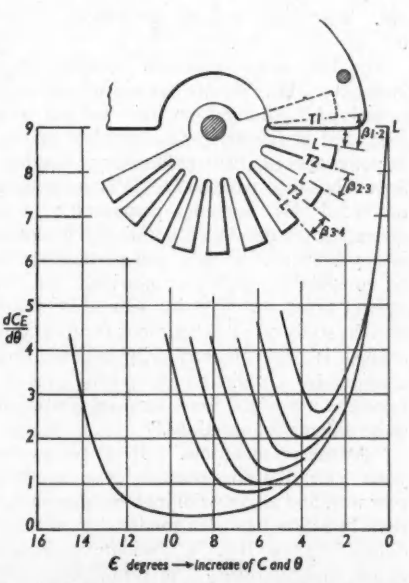


Fig. 9—Curves of C_E minima for intersector gaps of various angular dimensions. Such curves are useful in deciding upon the shape of the moving plate for a decade condenser

to those of $dC_{E(L)}/d\alpha$ given in Fig. 7 for various angles β of separation between adjacent moving plate fingers. The results of this are given in Fig. 9 for the angles of separation of the actual moving plate used in the decade condenser being investigated—the plate sketched as an inset to the curves. It is to be expected that the minimum value of $dC_E/d\theta$ will rise rapidly as the angle of separation is reduced and it is seen from the curves that this method of reducing the value of $dC_E/d\theta$ is of little value for separation angles less than 5 deg. or so. Because the leading edge capacitance is greater than the trailing edge capacitance in the vicinity of the mid-space position, it is seen that the angular position at which a minimum value of $dC_E/d\theta$ occurs is farther from the leading edge L than from the trailing edge T—it occurs always when the ratio ε/β is about 0·6 for all reasonable separation angles from $\beta = 5$ deg. to $\beta = 14 \cdot 5$ deg., such as have been used in the design of the present condenser.

A family of curves such as that of Fig. 9 is very useful in deciding upon the angular spacing of the moving plate fingers for various positions of the decade and the exact angles of those positions.

(To be continued)

Professional Engineers and the Future

SPEAKING in Birmingham last Friday, the secretary of the Engineers' Guild, Mr. J. G. Orr, said that Britain's industrial future might well depend upon whether the number of professional engineers could be doubled within the next fourteen years. Young men could not be expected to respond to that need in sufficient number, he suggested, unless immediate attention was given to the factors that influenced their choice of career. Mr. Orr referred to the recent Government report on scientific and engineering manpower (THE ENGINEER, November 2nd, page 607), which estimated that within the next three years the number of professional engineers must be increased by 30 per cent, by 70 per cent by 1966, and must be doubled by 1970. That report, he commented, did not say how such a great increase was to be achieved. One of the greatest paradoxes of Britain, Mr. Orr continued, was that while the contribution of the engineering profession to the country's prosperity was so essential, the responsibilities and difficulties of the work of engineers were so little understood or acknowledged by the community. A post-war survey of 725 engineering companies, Mr. Orr added, had shown that two-thirds of the directors had no technological qualifications, while 40 per cent of the companies had no technically qualified director. How, he asked, could young men be expected to study and carry heavy responsibilities unless there were good prospects for promotion? One or two of the largest companies had recognised the importance of promoting professional engineers to their boards with excellent results. This question, Mr. Orr urged, was the key to Britain's prosperity. The Engineers' Guild, he said, was bringing the problem to the notice of industrialists in the hope that there would be a steady improvement, sufficient to induce the young men of the future to become professional engineers. The Guild believed that there was a great deal to be done in improving remuneration, and increasing the prospects of promotion and general status.

LETTERS AND LITERATURE

Letters to the Editor

(We do not hold ourselves responsible for the opinions of our correspondents)

GEAR STANDARDS

SIR,—Dr. Merritt's article on "British Gear Standards," in your October 19th issue, should be welcomed by all who value the prestige and technical competence of the gear industry and the British Standards Institution's part in it. There should be no criticism of the fact that he has put forward his views in the technical press rather than at a meeting of the Gear Committee, of which he is a member. The latter course would almost certainly result in a round trip from the North in his own time at his own expense with his notes still in his pocket. The tyranny of the fixed agenda, with its list of wearying detail, must be observed ; one cannot very well raise the subject of direction of effort as a matter of urgent public importance. Of course, he could have put down a motion, but the result would have been the same.

In his review of the present position Dr. Merritt has covered the ground so thoroughly that one discusser cannot do more than deal with parts of it. The question in the leader, "Are Gear Standards Wanted ?" is rhetorical ; there is no doubt in my mind that British Standards for Gears, the best that we can make them, can be extremely useful to the designer and manufacturer ; the only trouble is that the user has to wait so long for them.

The writing of gear specifications is a continuing process ; they seem to be constantly under review. The committee is never formally dissolved and reconstituted, the members meeting from time to time over the years as new trends of thought occur to them, or under pressure from outside. I went to my first meeting just ten years ago with the idea that I had been called because I was presumed to have some knowledge of gear manufacture which might be of value in committee. At that time I thought it might be possible to produce a fairly useful standard at one go. But I have learned that the best you can do is to produce a standard, issue it, and continually revise it in the light of experience and development in related fields until it eventually hardens into a rounded something difficult to improve further. All this takes time, more than an impatient one would like to give to it could he have foreseen this at the outset.

One reason for the slow progress is the voluntary nature of the work ; the B.S.I. provide office and secretarial facilities, but the members give their time and experience freely and without reward, not even a credit line in the standards they help to compile, or out-of-pocket expenses, in most cases supplied by the firms or organisations they represent. They are busy men in daily practice, so that all thoughts on standards problems between meetings are usually crowded out. This is not an easy one to solve. It might help if the committee secretary had fewer committees to care for, so that he could give more time to each one ; the gear work, in particular, needs concentration and considerable knowledge of the subject.

Should a gear standard include detailed explanation of its subject-matter ? This leads to the criticism that it is on the way to becoming a textbook. There's a balance in all these things, and it's up to us to find that balance. The last revision of B.S. 721, "Worm Gearing," issued 1941, gave design rules for diameter factor, a new conception at the time, without adequate explanation ; this led to a flood of queries and correspondence in the technical press. Nothing likely to further the acceptance of a standard should be rigidly excluded.

The definition of the basic rack of the system, standard pressure angle and so on is the foundation of any gear standard ; it enables stock tools to be made, a most important consideration. Dr. Merritt is now inclined to the view that strength, wear, and rating formulas should come out, but I believe they should be included, because they are often used in preference to more elaborate methods of calculation. In the absence of anything better, the rules given in B.S. 545/49, "Bevel Gears," should be retained, and those in B.S. 436, "Spur Helical Gears," last revised in 1940, brought into line in the method of presentation. Dr. Merritt refers to B.S. 2519, "Glossary of Terms and Notation." The title is as stilted as the contents ; this is a real academic exercise. All our old familiar terms are banished. "Correction" becomes "diameter modification." "Standard Pitch Circle" is now "Cylinder of Generation," or "Reference Cylinder." And so on. This departure from long-established well-understood usage only serves to confuse. We already have "Reference Diameter" in place of "Proof Diameter" (hobs, cutters, master special gears). The old homely terms should not be thrown over merely because they are old. They mean something to most of us ; the new ones don't.

My last point concerns Symbols and Notation. Dr. Merritt has himself devoted considerable thought to this subject and published proposals for a complete system as long ago as 1930 (*Machinery*, London, September 4th, page 719). It is interesting to recall his opening paragraph : "A systematically developed notation is essential in any branch of science, and particularly in so complex a subject as gearing. At the present time such diversity of practice exists that the study of published work from various sources is made unnecessarily difficult, and considerable confusion frequently results from the use of the same term or symbol in quite different connections."

"At the present time." Here, twenty-six years later, the confusion is as great as it ever was, and any possibility of change in the right direction has been rendered even more difficult by the B.S.I.'s obstinate insistence to get the "Glossary" in print. It is still urgently to be desired that a common symbol system should be evolved between this country and the U.S.A. in the first instance, and possibly on an international basis at a later stage. During my years at the Admiralty I made many attempts to bring this about, all to no purpose. The American Standard "Letter Symbols for Gear Engineering" was published in 1943, ten years before the British effort appeared. I tabled a copy at a B.S.I. gear meeting in 1947, urging its adoption. I went to see the Director of the B.S.I. I had much correspondence with the Secretary of the I.Mech.E., stressing the "educational" aspect and the teaching in engineering schools. I called a special meeting of "Service" interests. But nobody cared.

Even a limited agreement at this late stage would be welcome. The essential differences are few. They are :—

	American (1943)	British (1953)
Pressure angle	ϕ (phi)	ψ (psi)
Helix angle	ψ (psi)	σ (sigma)
Number of teeth ...	N, n	T, t
Circular thickness ...	t	g
Base diameter	D_s	D_b
Outside diameter ...	D_b	J

It would appear a perfectly simple matter to get this elementary reform under way. But there is not the slightest sign of any change of heart. If this is symptomatic of the general outlook, then the hope of resolving the differences in more fundamental issues referred to in Dr. Merritt's article is poor indeed.

A. M. GUNNER

Hampton Wick,
November 6th.

HOW TO AVOID BUILDING NEW ROADS ?

SIR,—I have followed with interest your persistent campaign in favour of the introduction of a road system in the British Isles. A point which I would like to make in this connection concerns the positive harm which can result from the activities of those in authority. I was driving at night through Chiswick recently and saw what appeared to be some new road sign—it was rather high and ill-lit, but had the sort of shape which is associated with road news, a diversion or a route number, rather than with an advertisement. I, therefore, found myself involuntarily compelled to look up at it, and as it was ill-lit, I had my eyes off the press of traffic for perhaps three-fifths of a second—about 25ft of road. Some trace of an eye I must have kept on the road, for I did just manage to avoid nicking a cyclist with no rear light. The sign read "No Accidents, Please." The incident left me in a furious and probably dangerous mood which was revived from time to time as I saw more of these signs, many of them well-lit. It was at least 2 miles before I learned automatically to ignore them and concentrate on my driving.

But, sir, the point which I wish to make is that, since the authorities have apparently decided that exhortation is still cheaper, as it always has been, than roads, it is our public duty to attempt to make this policy work, rather than to criticise. What is

obviously required is a sign that can be comprehended instantaneously, and which is really effective. I have a suggestion to offer, inspired by the reminder of my drive that night. Further out towards Bath, I saw two large smashes, both recently littered across the highway. For about 5 miles after each place everybody drove very carefully. Obviously, sir, we should have "property" smashes about every 5 miles along all our major roads. Smashed vehicles must be readily obtainable and perhaps Madame Tussaud could be persuaded to help! True, after a while the public might become inured to such sights, and a few genuine smashes might remain undetected until the victims were beyond all help, but that is surely a small price compared with the money we would save by not building roads!

Chippenham, Wilts, D. L. REEVES
October 31st.

FOXCOTE RESERVOIR

SIR,—In the article on the design and construction of the embankment for the Foxcote reservoir at Buckingham, which appeared in your issue of November 2nd, the unfortunate impression is given that this embankment has been designed with "a safety factor of at least unity." Obviously this cannot be the case and, in fact, at the present minimum strength the bank has a factor of safety of something like 2½. However, as the article points out, there will be some reduction in strength with time and this has been taken into account in the design. Measurements on railway cuttings and embankments in similar clays have, it is true, indicated a figure of 400 lb per square foot as the ultimate value of shear strength, but this figure is not applicable to the Foxcote embankment because of the drainage and compaction control provided there. It is not expected that the strength will be reduced below 600 lb per square foot with a final factor of safety of at least 1½.

BINNIE, DEACON AND GOURLEY
Westminster,
November 7th.

[What we actually printed was "Design of the dam was based on the conventional $\phi=0$ analysis, assuming a shear strength of 400 lb per square foot, giving a safety factor of at least unity. Undisturbed samples of the clay gave a minimum shear strength in unconfined compression tests of 1000 lb per square foot."—ED., THE E.]

"NEVER BE SHORT OF LABOUR"

SIR,—There appears to me to be a fallacy in Mr. Semler's line of argument. He says "A general reduction in the cost of manufactured goods would leave so many people better off that there would be an increased demand for goods and services, particularly luxuries which are not usually produced by automatic means." First, the wages of a large section of the working population are governed by the cost of living index, and if this falls, presumably wages will be decreased, and, secondly, directly goods are cheap and plentiful this gives rise to inflation which is countered by an increase in the purchase tax, so putting these goods out of the reach of the many.

J. F. PERRIN
Carlisle, November 3rd.

Literature

Metallurgy of the Rarer Metals; No. 5. Molybdenum. By L. NORTHCOTT. Butterworth's Scientific Publications, 88, Kingsway, London, W.C.2. Price 40s.

THIS latest addition to the series of books dealing with the metallurgy of the rarer metals well maintains the high standard of the previous volumes. Dr. Northcott has been actively associated with researches into many aspects of the metallurgy of molybdenum and thus, in the preparation of a comprehensive review of the whole subject, has been able to contribute knowledge gained by himself and his associates on problems connected with the melting, casting and fabrication of the metal and with the application of protective coatings.

The book is divided into nine chapters, which cover the occurrence, extraction, production by powder-metallurgy methods and by arc-casting, properties and uses of molybdenum; alloys of molybdenum and their mechanical properties; the oxidation and protection of molybdenum; and the joining (soldering, brazing and welding) of the metal. The book is not overloaded with unnecessary detail, but a wise selection has been made of the most trustworthy data contained in the very large number of papers dealing with the properties of molybdenum and its alloys which have been published during the last ten years. An extensive bibliography is, however, provided in each chapter. The classification of the molybdenum-rich alloys on the basis of their equilibrium diagrams is preceded by a theoretical survey and valuable discussion in the light of the Hume-Rothery rules of the solid solubility of the elements in molybdenum. Of special interest in view of future developments are the chapters on protective coatings to withstand oxidising conditions, and on the joining of molybdenum, especially the sections on welding processes and the assessment of the most promising welding techniques.

High melting point (2620 deg. Cent.), high rigidity (Young's modulus 45×10^6 lb per square inch) and good creep resistance at high temperature are important characteristics of molybdenum, and the critical assessment of its properties and those of its alloys will make the book specially valuable to those interested in the possible engineering applications of molybdenum and molybdenum-rich alloys for use at high temperatures.

Computers; Their Operation and Applications. by EDMUND C. BERKELEY and LAWRENCE WAINWRIGHT. Published by Chapman and Hall, 37, Essex Street, London, W.C.2. Price 64s.

THIS book is concerned with digital and analogue computers in general terms. The construction of these machines is dealt with as a series of black boxes having a function to perform, with only the barest outline of the contents of the various boxes. It goes on to illustrate these by the authors' computer "Simon"—a very simple training machine built in 1950. This is followed by a few particulars of the major commercial machines of Remington Rand and International Business Machines. Criteria are tabulated by which to assess computers, but the data given on the commercial computers are not sufficient to enable a reader to apply them to these. For buyers and potential users it provides a glossary of terms in current use in U.S.A.: this adds somewhat to those compiled by the British Standards Institution. To this is added a list of computer builders and their products reprinted from the magazine *Computers and Automation*, and a poll of opinions of executives in various U.S.A. industries as to the usefulness of computers.

An interesting question is raised, "Whose work will computers do?" and an answer attempted based on U.S.A. census and limited market research on applications. But it hardly needed market research to justify the main conclusion that the biggest factor in the attitude of a great many prospective buyers is whether a potential saving exists and that if a really substantial saving can be shown, then the buyer is definitely interested. Many applications are referred to shortly, about two paragraphs each with the exception of payroll work, so that little can be deduced from them. The reason given for reporting these is that it is easier to apply computers to do a job to which others have already applied them. The book abounds with such obvious conclusions.

Progress in Semi-Conductors. Volume I. Edited by ALAN F. GIBSON, B.Sc., Ph.D., PROFESSORS R. E. BURGESS and P. AIGRAIN. Heywood and Co., Ltd., Tower House, Southampton Street, London, W.C.2. Price 50s.

THE difficulty of keeping abreast of recent progress and current trends is specially acute in those subjects, such as semi-conductors, where knowledge is advancing rapidly. Every year the specialist working on semi-conductors must needs study and digest the contents of several hundred papers from various sources. An attempt to simplify this task is made in this book, for it is intended to be the first of an annual series of volumes, each containing a number of review articles written by specialists on semi-conductors. The potential usefulness to the reader may be gauged from the contents of Volume I. It contains articles on recent advances in silicon, by N. B. Hannay; the germanium filament in semi-conductor research, by C. A. Hogarth; the theory of the Seebeck effect in semi-conductors, by V. A. Johnson; the electrical properties of phosphors, by G. F. J. Garlick; the design of transistors to operate at high frequencies, by J. Evans; photo-magneto-electric effect in semi-conductors, by O. Garreta and J. Grosvalet; and the field effect in semi-conductors, by L. R. Godefroy. Each article is followed by a full list of the references upon which the review itself is based. The fact that 470 references are quoted in these articles gives some indication of the scope of the work and the scholarship involved.

Books Received

Graduate Employment, "A Sample Survey." Political and Economic Planning, 16, Queen Anne's Gate, London, S.W.1. George Allen and Unwin, Ltd., 40, Museum Street, London, W.C.1. Price 30s.

Engineering Mechanics. Fourth edition. By S. Timoshenko and D. H. Young. McGraw-Hill Publishing Company, McGraw-Hill House, 95, Farringdon Street, London, E.C.4. Price 56s. 6d.

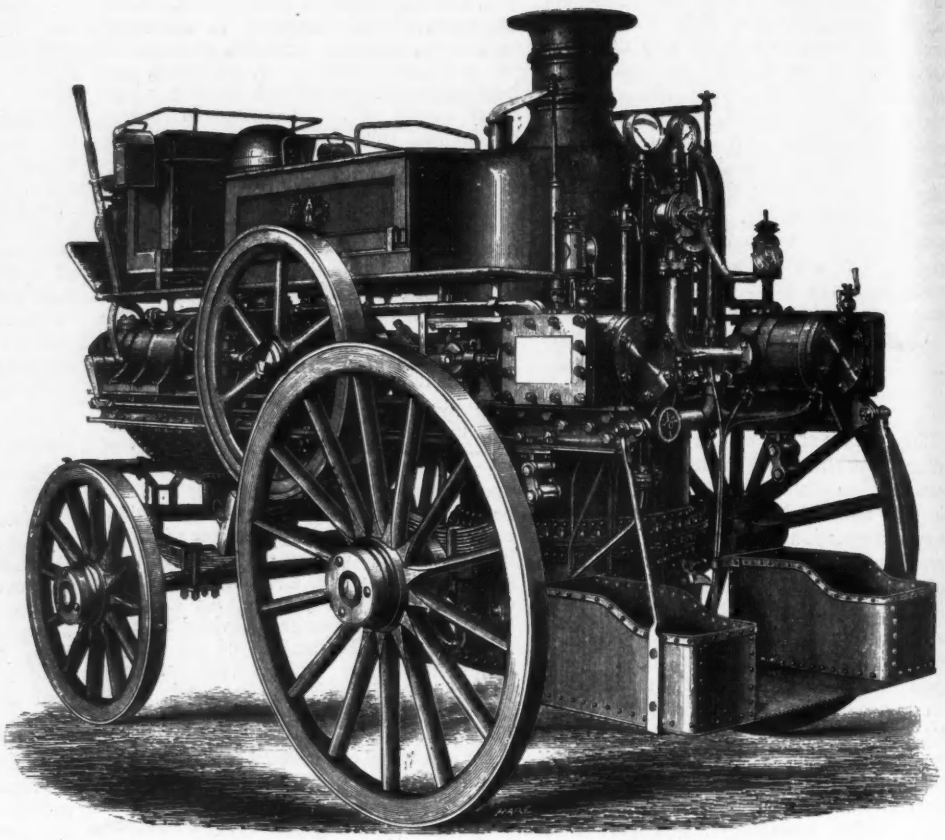
Reports on Progress in Physics. Volume XIX. Executive Editor, A. C. Strickland. The Physical Society, 1, Lowther Gardens, Prince Consort Road, London, S.W.7. Price to non-Fellows £2 10s.; price to Fellows £1 7s. 6d.

Electro-Technology for National Certificate Courses, Volume 2 (Technical College Series). By H. Buckingham and E. M. Price. The English Universities Press, Ltd., 102, Newgate Street, London, E.C.1. Price 12s. 6d.

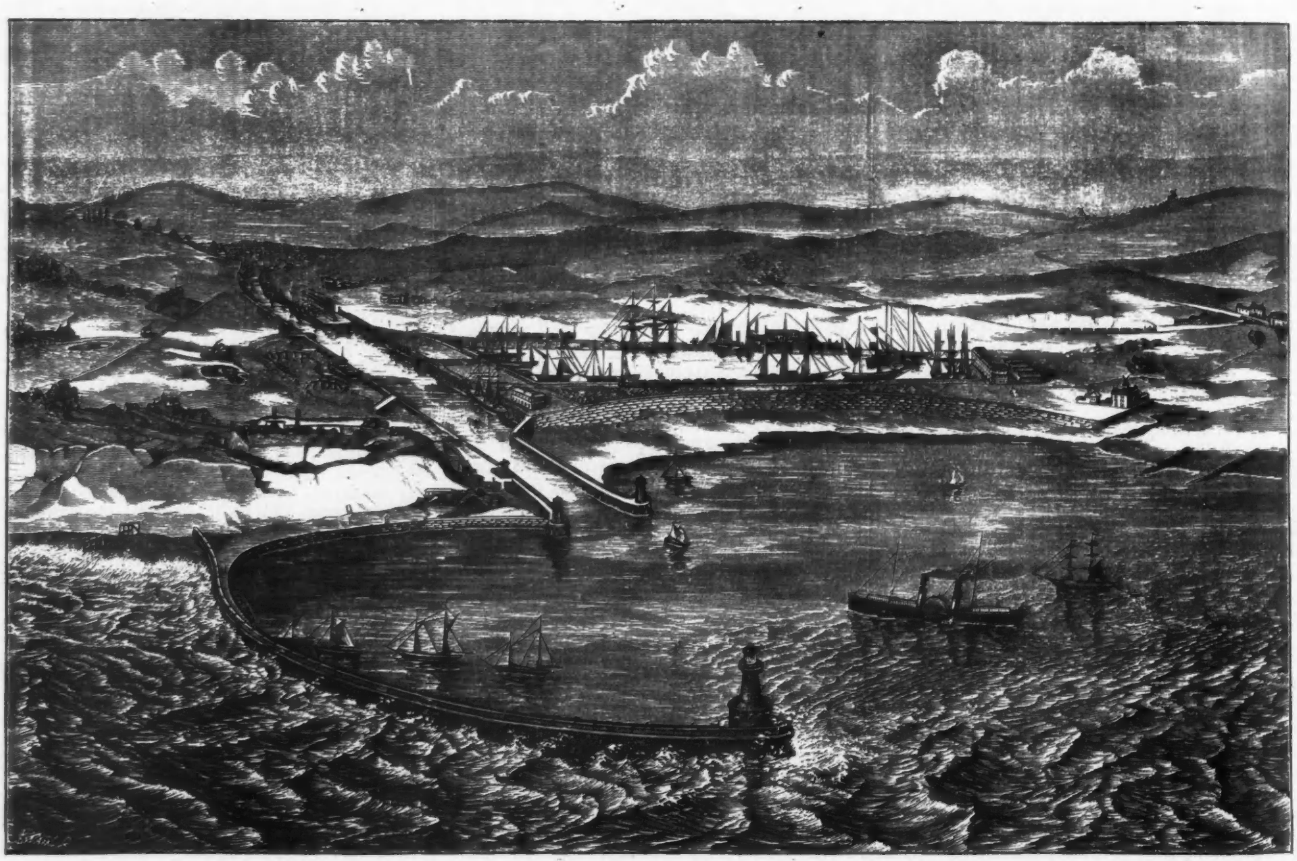
The A.S.E.E. Guide to the Thirteenth Edition of the I.E.E. Regulations for the Electrical Equipment of Buildings. Compiled and published by the Association of Supervising Electrical Engineers, 23, Bloomsbury Square, London, W.C.1. Price bound in paper covers 5s., price bound in cloth covers 7s. 6d.

ENGRAVINGS OF 1878

The portable steam pumping engine, illustrated by the right-hand engraving, was built by Shand, Mason and Company. A description of it, in our issue of October 18, 1878, explains that it was constructed at the request of the engineer to the Southwark and Vauxhall Water Company, who had "found it necessary to use one of the maker's steam fire engines for temporary pumping purposes." The article goes on to say that "the engine is stoked from the hind foot plate, on which are fixed the coal bunkers. The pumps are on the treble equilibrium principle, laid horizontally in the front, and firmly bolted to the framing." The description adds that "the engine can be drawn on good roads by two horses at a rapid rate. Steam can be got up and the engine put to work in the space of fifteen minutes, and has delivered 78,000 gallons per hour."



The engraving (below) showing the Newhaven harbour extension, is reproduced from our issue of December 13, 1878. It illustrates a plan devised by Mr. F. D. Bannister, M.I.C.E., engineer to the London and Brighton Railway, for increasing the accommodation in the harbour. Our article says that the proposals included the construction of a breakwater about 1000 yards in length, to be run out seaward from the shore at Barrow Head; the extension of the two entrance piers, and widening the entrance from 150ft to 200ft; the construction of a new wharf or quay between the Mill Creek and the eastern entrance pier, and the construction of "durable sea walls."



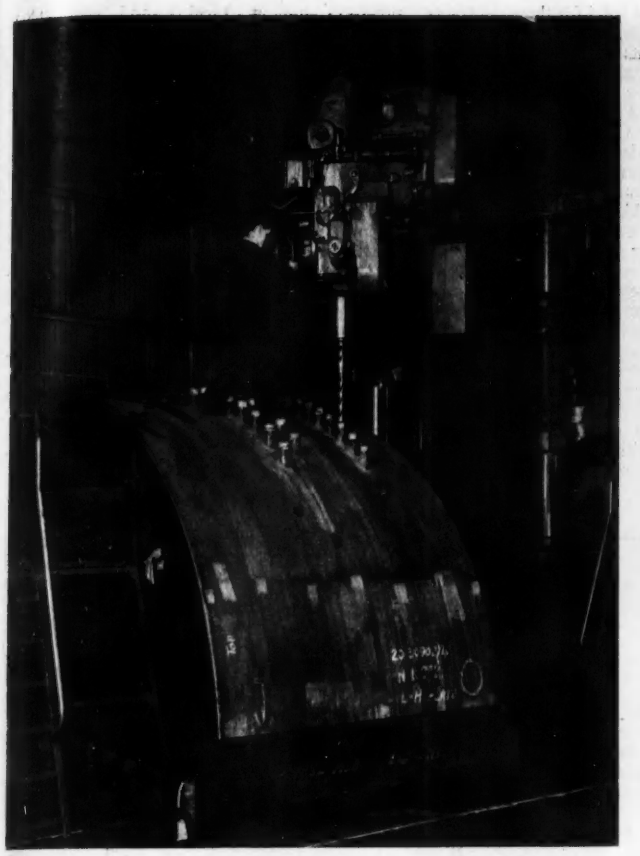


Fig. 1—Drilling the thermal sleeves in a sector of a heat exchanger shell

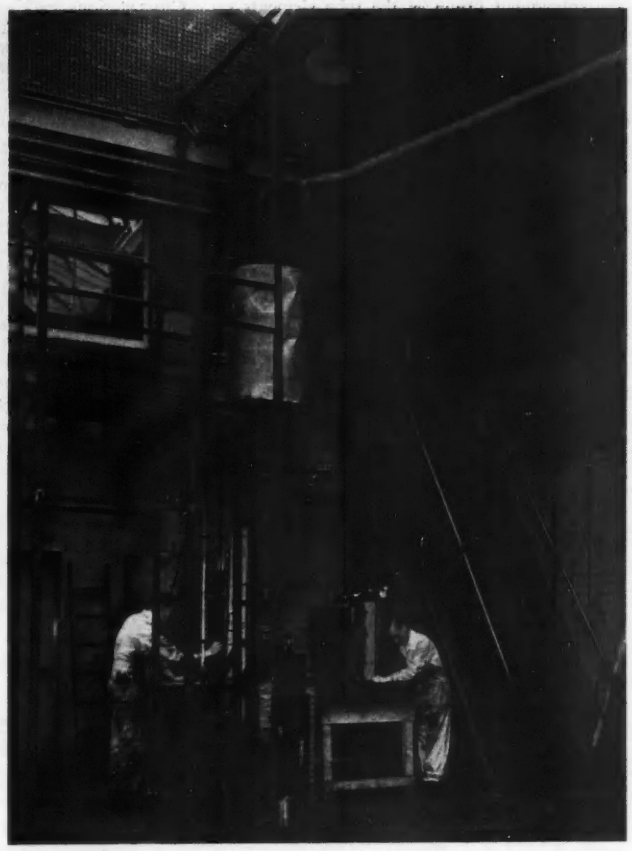


Fig. 2—Quick-sorting rig for heat transfer and pressure-drop tests on fuel cans

Developments in Nuclear Power Engineering at Renfrew

Facilities for manufacturing nuclear power plant, and for research to back this effort, built up by Babcock and Wilcox, Ltd., are described here. They include a 2000-ton press for forming shaped plates, up to 7in thick, for pressure vessels. Production lines have been set up, in the existing tube and drum shops, for the manufacture of heat exchanger sections and the associated steam raising towers. A new tube and manifold shop has been built and equipped. Development work on pressure vessels, heat transfer, fuel canning materials, metallurgy, ultrasonic flaw detection and other aspects of nuclear power engineering is carried on at the company's research station near the Renfrew main works.

LAST week we visited the Renfrew works and research laboratories of Babcock and Wilcox, Ltd., to see something of what the company is doing in the development of nuclear power engineering. The bulk of the company's effort in this field has been devoted to the production of heat exchangers for the gas-cooled graphite-moderated natural uranium reactors of the Calder Hall power station. Already the manufacture of all the sixteen heat exchangers for the "A" and "B" stations has been completed. The work of making the heat exchanger sections and fabricating the heat exchanger tower sections was done initially in the existing tube, drum and plating shops, side by side with the steam raising plant involved in the normal order book. As the work progressed, building up to a peak in 1954–55, improved production facilities were created in these shops, until to-day there is an imposing production line of heat exchanger sections and components for the steam raising towers for the Chapel Cross stations of the United Kingdom Atomic Energy Authority at Annan in Scotland.

With its experience of fusion welded drums for high-pressure steam generating plant, the company is also interested, naturally, in the design of large-diameter pressure vessels for nuclear reactors. In the near future the demand is likely to be for larger vessels and increased pressures which could be met by the use of improved steels, without unduly increasing the thickness of the plates. The company is, therefore, working in close collaboration with the steelmakers, to obtain further improvement in the characteristics of available steels. In the design and manufacture of large vessels for nuclear applications requiring very high pressure involving unusual forms of construction, the company is also making arrangements for half-scale versions to be manufactured for testing to destruction in the research department, after which a part-version of a full-scale vessel will be similarly tested.

The company is to build the reactor vessel for Canada's first nuclear power plant, which is also the first in the Commonwealth outside Great Britain. It is to be a pressurised heavy-water reactor and the vessel housing it will be about 12ft in diameter and 35ft high. The design provides for a pressure of 1200 lb per square inch, with a shell thickness of 5in, increasing in places to 6½in. Of the total weight of 210 tons, 70 tons is in the head, which is bolted on because it is required to be demountable, allowing full-way access into the vessel. The head will contain many smaller openings, and each of these openings will have its own closure.

It may be recalled that Babcock and Wilcox, Ltd., recently announced the formation of an atomic energy department with Mr. T. B. Webb as manager, under the direction of Mr. W. F. C. Schaap, director and chief engineer of the company. This department is based in London, where much of the design and project work in nuclear developments is taking place. Next year the company is to install a Ferranti "Pegasus" electronic computer in its new head-office building at 209, Euston Road, London, N.W.1, which will provide valuable assistance in the complex work of nuclear engineering design.

Manufacture

The drum shop was originally laid down for the building of steam drums for high-pressure boiler plant and much of the productive capacity of the shop is still engaged in this class of work. The shop has, however, been considerably reorganised and re-equipped to provide, in addition, a production line for the large diameter sections of steam-raising towers for nuclear power plants.

On our tour of the shops we saw some of these 17ft 6in diameter sections being fabricated for the Chapel Cross power station. It will be recalled that the steam-raising towers for Chapel Cross are of the same design as those supplied for Calder Hall "A" and "B" stations. Each tower is finally fabricated on site from six cylindrical sections and top and bottom domed ends.

Before any work is done on the tower shell plates in the drum shop, the plates are examined by ultrasonic equipment for detecting flaws, the tests being carried out at the mid-points of the sides of the rectangular plates. Each plate is then shot-blasted and marked off preparatory to machining the edges of the plates to the weld profile. The plates are then bent to cylindrical shape and marked off ready for the drilling of the thermal sleeve holes; these sleeves provide means for the heat exchanger tube-connections to pass through the shell to the various manifolds and steam drums which are external to the tower. To give the required accuracy for

the subsequent fitting of the tube elements on site, the holes for the sleeves are jig drilled. The thermal sleeves are preheated and are then located for welding, on an internal tube fitted into the hole in the shell. After welding this locating tube is drilled out (Fig. 1), and the inside of the sleeve is bored to finished size.

Leak-tightness of the weld is tested by blanking off the sleeve with a special jig incorporating a connection for a compressed-air line and fitted with rubber joints. By this means the inside of the blanked off sleeve is subjected to pressure by a 50 lb-per-square-inch air supply containing halogen gas. At the same time a B.T.H. halogen leak detector is used to explore the outside of the fillet weld (Fig. 3).

In the same drum shop the domed ends for the steam-raising towers are fabricated from the segmental plates previously hot formed in the 2000-ton hydraulic press described below. After radiographic examination of the inter-segmental seams the domed end is passed to the machine shop for edge turning in preparation for welding to the adjoining cylindrical section of the tower.

Cross stations, making a total for these contracts of about 340 million studs.

The tubular elements are bent cold after studding and a special shoe is used to prevent damage to the studding in this process. Hot bending is not required for the comparatively thin-walled tubes of the Calder Hall and Chapel Cross heat exchanger elements, but during our tour we saw the process of hot close bending being used for the manufacture of superheater elements for orthodox high-pressure boilers and this process is equally available for the higher-pressure heat exchanger elements that may be used in future nuclear power plants. Complete tubular sections are assembled in jigs from one- two- or three-bend elements, the interconnections being made by hand welding.

The completed sections are braced with steel straps for support during handling and shipment, and every section is hydraulically tested before despatch. Before despatch, also, a proportion of the sections is given a special hydrogen test which is extremely sensitive to minute leakages. The sections, selected at random, are passed into

precision milling, turning and gear cutting equipment.

Research

In its research station near the Renfrew Works, the company's research and development department employs a staff of over 270. The laboratory is equipped for chemical and physical testing and analysis, mechanical testing, metallurgical examination and the application of electronics to engineering. This staff and equipment is engaged in research and development work concerned with the design and manufacture of steam-raising plant and with heat exchange problems and similar work on reactors and pressure vessels.

Here we refer briefly to some of the nuclear engineering work done by the research department.

Chemical Department.—Compatibility tests are being carried out on materials suitable for the fuel cans which contain the uranium fuel in a nuclear reactor. At present the working temperatures are of the order of 400 deg. to 450 deg.

Fig. 3—Halogen gas tests of welds between thermal sleeves and shell

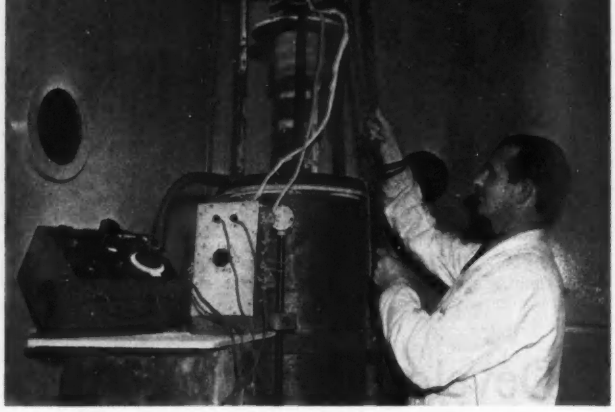


Fig. 4—Temperature cycling tests on reactor fuel element and can

The domed end is completed by the welding-in of the large-diameter gas connection after the mating faces have been ground and hand lapped to give good contact.

Facilities for forming the dished segments and other specially shaped plates needed in the construction of heavy pressure vessels are provided by a recently-installed 2000-ton hydraulic press. It is of unusual design in that the power-operating cylinders are installed in a 40ft deep pit. A sliding table carrying the lower die facilitates the positioning of the plate after preheating in the adjacent furnace, which serves the press. Control is by a single operator from a central panel. This press is capable of dealing with plates up to about 7in in thickness, and will be required for the forming of plates for such items as reactor pressure vessels, of which a typical example is the one for the Canadian pressurised heavy-water reactor which is 12ft in diameter and 35ft high.

In gas-cooled reactor plants the heat exchanger tubes are required to be clean both internally and externally, and, as the Calder Hall and Chapel Cross plants are designed for operation at relatively low pressure, the requirements are most suitably met by electric resistance welded (ERW) tube. After inspection of the tubes, the special aerofoil studs (accurately cut to length on an automatic machine from elliptical section strip) are welded on by a battery of semi-automatic welding machines which were developed by the plant department of the Renfrew works.

The number and arrangement of the studs vary according to the particular heat exchanger sections for which they are destined. The superheater sections are made from plain tubes, with no studding. Nearly 11,000,000 for each of the thirty-two towers for the Calder Hall and Chapel

a test house, where each is enclosed in a gasproof envelope which is filled with hydrogen and the tubes are evacuated to a high degree. Any hydrogen leakage, at a weld or elsewhere, is detected by sensitive electronic equipment. Initially, all the tube sections for Calder Hall were subjected to test in this way, but as no leakage was found the proportion of sections selected for testing has been reduced, with the approval of the U.K. Atomic Energy Authority, to about 20 per cent.

Construction of manifolds for the Calder Hall type of heat exchangers follows the normal procedure adopted for manifolds on low-pressure boiler plant, using large-diameter seamless steel tubes with forged ends. The manifold department handles a wide variety of large headers, many with a complex arrangement of stub connections, and fabricated in alloy steel for operation under high-pressure and temperature conditions. After welding, all manifolds are fully stress relieved and hydraulically tested, and the stub ends are profiled, before despatch, in preparation for site-welded interconnections.

The new tube and manifold bays are among the largest in the Renfrew Works, each being 100ft wide and 700ft long, and equipped with three overhead travelling cranes, each of 10-ton capacity, enabling large assemblies to be handled. In addition, the older tube and manifold shops have been reorganised to provide facilities for tube bending, welding, studding, testing and stress relieving, and they are at present closely engaged in producing the tubular elements for the Chapel Cross heat exchangers.

The general machine shop has recently been reorganised to provide improved production flow lines, and equipped with about 300 machines, including large horizontal boring machines and

Cent. when using uranium with a carbon dioxide atmosphere and a graphite moderator. The special requirements for these cans are a material having adequate strength and ductility at high temperature, good heat transfer, low absorption of neutrons and compatibility with the fuel and coolant. Materials for this purpose under present investigation include magnesium alloy such as "Magnox," and other materials with low neutron absorption such as zirconium alloys. Equipment is also being designed for a prolonged series of tests to examine the corrosion effects of these and similar materials in a carbon dioxide atmosphere at high temperatures under dynamic conditions, and investigations are envisaged into the chemical problems, such as compatibility, associated with liquid-metal reactors.

Long-period scaling tests have been carried out in connection with materials for high-pressure boilers fired with a wide variety of fuels, and the results are extrapolated to the equivalent of 100,000 hours of service. The apparatus can readily be adapted to investigate the performance of materials used in nuclear power plant construction, under conditions simulating those of actual operation.

A new extension to the chemical laboratory will include additional spectrographic equipment to facilitate analysis of new or unusual materials likely to be used in nuclear equipment, where determinations of minute trace elements may be of considerable importance.

Metallurgical Department.—The effect of temperature cycling on canned fuel elements, involving metals of different expansion characteristics, is examined in a rig (Fig. 4) in which a sample fuel element comprising a uranium rod enclosed in a "Magnox" can is subjected to

changes of temperature corresponding with insertions into and withdrawal from a reactor. The sample fuel element enclosed in a steel tube containing argon gas is lowered into an electrically heated chamber (Fig. 4), maintained at about 400 deg. Cent., and is periodically removed and cooled to room temperature. Several thermo-couples, placed at intervals along the steel container, enable accurate temperature readings to be taken. The " ratcheting " effect that may result from the unequal expansions of fuel rod and can is observed by means of X-ray photography.

Mechanical Department.—To assist in the design of reactor pressure vessels, and of reactor components subjected to varying pressure and temperature conditions, the mechanical department is engaged in studies of the performance of materials used in reactor construction. They involve a variety of orthodox mechanical tests, with particular attention to such aspects as brittle-fracture related to special alloy steels, and the creep properties of steel and of light non-ferrous alloys.

Fatigue tests on such materials are carried out by conventional reverse-bending at various speeds at room temperatures and increased temperatures and, in some cases, with corrosive liquids applied to the specimen. In addition, slow tensile fatigue testing of large specimens at working temperature is being done in test rigs constructed in the station workshops.

For hot-rupture tests, a bank of eighty-four hot-stress-rupturing machines (Fig. 5) is installed; many of them are at present engaged on samples of the " Magnox " alloy used for fuel cans. The number of machines devoted to such tests will be much increased shortly by a new extension now being made to the laboratory, which will house additional hot-stress-rupture machines.

The design of conventional high-temperature steam-raising plant requires data from hot-rupture tests only, as permanence of dimensions is not of primary importance. In certain nuclear applications, however, the amount of creep strain is important; therefore, twenty-four creep testing machines are also being installed. This extension will greatly facilitate tests on alloys of aluminium, beryllium, zirconium and on other materials developed for nuclear power applications.

The study of pressure vessel performance, including testing to point of failure, forms an important part of the work of the mechanical research department, where there has been installed since 1952 a Werner and Pfleiderer pulsating pressure plant capable of hydraulic fatigue testing full-size pressure vessels up to 4500 lb per square inch. A new extension of about 3600 square feet area will enable more space to be devoted to these tests and accommodate large-scale versions of such pressure vessels as prototype reactor chambers. To deal with the higher pressures envisaged for all kinds of vessels additional pulsating hydraulic test plant is being installed for pressures up to 6000 lb per square inch.

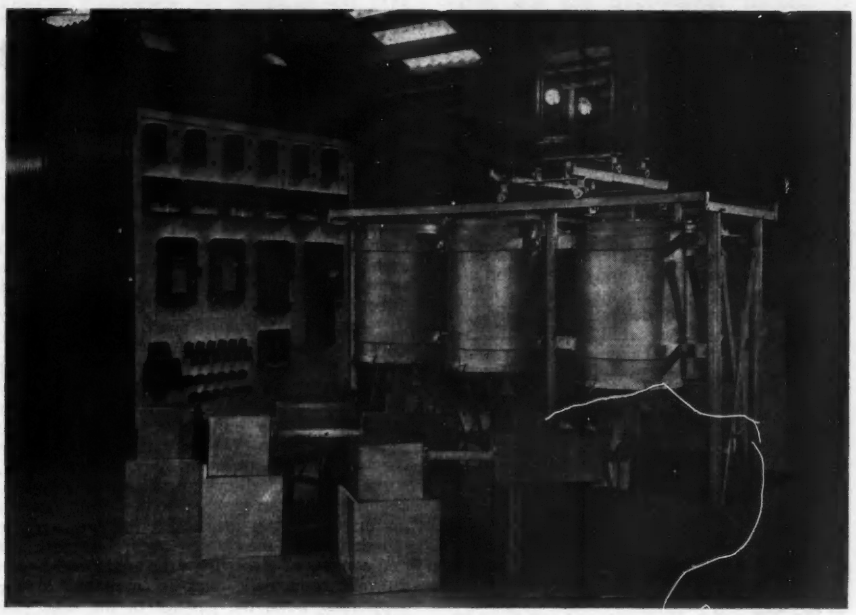


Fig. 6—Corrosion testing of metals

Heat Transfer Department.—Tests are done by passing hot gases over test assemblies of heat exchanger tubes having a wide variety of extended surfaces, under a controlled range of conditions. The test assembly of heat exchange elements with its water-circulation arrangements, is located in a vertical flue in the hot gas flow from a remote oil-fired combustion chamber, the equipment being designed to simulate the hot gas flow conditions in the steam-raising towers of a nuclear power plant. Provision is made for control of gas and water flow and temperature conditions, and for various measurements relating to the heat transfer efficiency of the various surfaces. A more advanced boiler heat transfer test rig using a closed gas circuit at elevated pressure is now being designed and when installed will permit testing at considerably higher temperatures and heat rating than the present equipment.

" Quick-sorting " tests are carried out on a great variety of fuel cans with different experimental extended surfaces; by means of these tests the less effective designs can be quickly eliminated and development concentrated on those offering the greater promise. In this rig (Fig. 2) representative fuel cans are steam heated in a lagged cylindrical vessel through which air is circulated, simulating gas-flow in a reactor. Measurements indicate both the air-pressure drop along the surface of the can and the effectiveness of heat transfer. About 300 different designs of can have so far been tested in this way. An interesting result is that in some instances the introduction of deliberate asymmetry in the finning of the cans has resulted in improved heat-transfer performance.

For a closer investigation of the behaviour of the more promising designs of fuel can a more elaborate test rig has been developed, which gives better simulation of the actual conditions in a gas-cooled reactor.

In this apparatus the fuel can is located inside a steel pipe forming part of a closed circuit in which carbon dioxide is circulated under pressure and the fuel rod is simulated by an electrically-heated element inside the can. Facilities are provided for a wide variety of measurements of flow, pressures, temperatures and electrical input to the fuel rod, to enable the heat transfer and gas flow-resistance characteristics of the can to be accurately assessed.

The heat rating of a reactor fuel element is so high that conventional methods of simulated heating which could be introduced to the confined space were inadequate, but an interesting method of overcoming the difficulty has been developed. The basis of the method is to use a highly-rated electrical heating element in the form of a flat-strip spiral insulated electrically from the inside of the can by a thin film of aluminium oxide which has good thermal properties. With an arrangement based on this principle a loading of 15kW per foot run of tube has been achieved.

Ultrasonic testing techniques are being developed for testing welds on site and we saw a simple rig devised for testing circumferential welds in pipes and tubes.

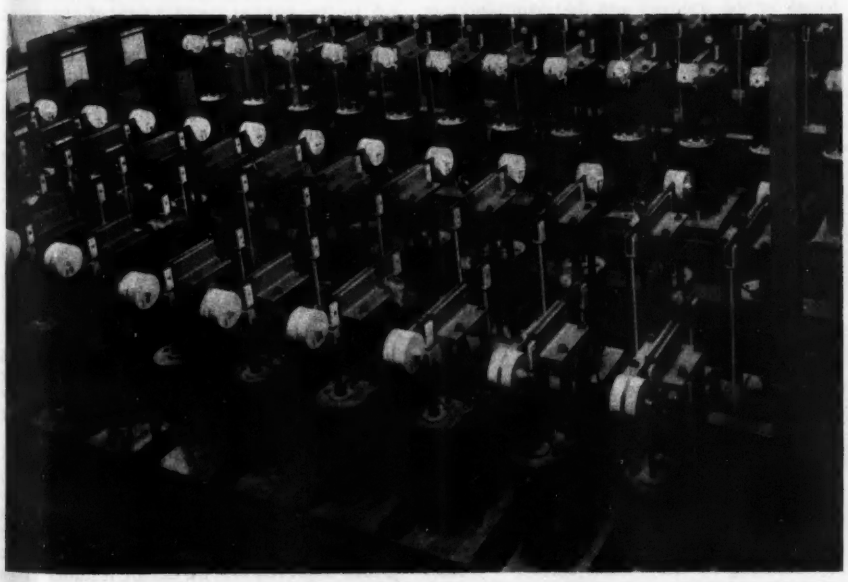


Fig. 5—Part of a battery of eighty-four hot-stress-rupturing machines

QUARTERLY MAGAZINE ON FLEXIBLE TUBES AND HOSES.—The first edition of a new quarterly magazine entitled *Arteries of Industry* has been received from the Compoflex Company, Ltd. This magazine is intended as a part of the firm's advisory service on flexible tubing and hoses. It is proposed that each issue shall contain articles by outside contributors on interesting applications of these products in various branches of industry, as well as up-to-date information on the manufacture and use of flexible tubes and hoses.

Development of the "Deltic" Engine

By C. D. CARMICHAEL, B.Sc.(Eng.), A.M.I.Mech.E., A.F.R.Ae.S.

The Manchester Association of Engineers last Friday heard an address on the subject of the "Deltic" engine designed and developed at the Acton works of D. Napier and Sons, Ltd. We reproduce below part of the paper.

Development Problems

WHEN the basic design features of the engine had been established and construction of an engine was decided on, the first problem in development was to determine as quickly as possible whether the detail interpretations of the basic scheme were capable of demonstrating the designed performance targets. This problem divided into two stages, first to determine whether the porting as designed was capable of trapping the designed quantity of air per cycle in the cylinder and, secondly, whether an injection system could be devised which would give efficient combustion of this air at the high operational speeds involved.

Both of these problems proved capable of solution on a single-cylinder test unit, and most of the early problems connected with a cylinder and piston design were, in fact, solved in units of this type.

As far as the achievement of the designed air flow was concerned no great difficulty was experienced and the problem was solved by the testing of a number of cylinder liners incorporating various combinations of port timings and port areas, from which the best combination was deduced.

The combustion problem, however, was rather more difficult and involved a considerable programme of work. Basically, the problem involved here is simple enough ; it is to distribute the injected fuel uniformly throughout the air in the combustion chamber, in the very short time period available so that the combustion of a very high percentage of the total fuel and air is completed within a few degrees each side of top dead centre. On some engines the combustion chamber is of such a shape that this problem can be dealt with by the provision of fuel sprays of a form which impregnate all the air present—that is, the fuel is sent to find the air. But the "Deltic" combustion chamber has the shape of a very thin cylindrical disc and it was found quite impossible to arrange any form of spray which would search out a practical proportion of the total air present, even when two injectors were used, this difficulty being accentuated by the fact that as the inner surfaces of the triangle formed by the cylinders are inaccessible, any injectors must be arranged on one side of the cylinder only, the maximum angle possible between them being only 100 deg.

It was, therefore, decided to use the system in which a high degree of rotation or "swirl" is imposed upon the air in the cylinder to produce a form of vortex, the forces exerted by this vortex on the fuel particles being used to transport the fuel from the outside of the combustion chamber to the centre and, at the same time, give good mixing of fuel and air. The mechanics of this system are complex and not capable of other than experimental determination in any particular case, but, using a spray pattern in which the fuel is directed towards the periphery of the combustion chamber, very satisfactory results have been obtained.

In the engine cylinder it is easy enough to produce the air swirl by the simple expedient of machining the inlet ports so that the air enters with a partially tangential direction. It is, in fact, surprising what high speeds of rotation of the air are obtained in this way, it being fairly easy to produce rates of swirl up to five or six times the crankshaft speed—that is, between 10,000 and 12,000 r.p.m. at maximum engine speed.

The difficulty is to decide upon the best degree of swirl to suit the whole range of operating conditions, for the engine performance is quite sensitive to variations in swirl, the response varying over the speed range.

To explore this matter a single-cylinder unit was modified by fitting a rotatable sleeve round the outside of the inlet port belt of the cylinder liner, this sleeve also having ports arranged in such a way that by changing the position of the sleeve relative to the fixed ports the effective direction of entry of air into the cylinder and, therefore, the degree of swirl, can be altered, even while the unit is running.

During the course of these investigations it was regarded as essential to find a means whereby the actual rates of swirl resulting from the various positions of the adjustable sleeve could be recorded, first, so that the unit results could be checked back to an actual liner, and, secondly, so that individual cylinders on the complete engine could also be checked for uniformity of performance. An instrument for this purpose was designed in the Napier Research Department and consists of a rotating vane anemometer with an electromagnetic pick-up mounted in the supporting boss, the passage of the vane past the pick-up being counted electronically and the swirl revolutions per minute displayed on a dial.

In parallel with these swirl tests much experimental work was also done with different designs of injector. Experiments in the unit indicated that the best results were obtained with the greatest possible angle between the two injectors, this angle on the complete engine being limited by interference between the injectors of adjacent cylinders. This clearly is dependent on the length of the injectors and the main objective of the experimental work was to develop the shortest possible injectors. The final design chosen was of the outward opening valve type. In spite of their small dimensions these injectors have performed extremely well, experience showing that a running time of 1000 hours or over may be expected without attention of any kind being required.

As the result of an extended programme on the items mentioned above the designed performance both for power and fuel consumptions was eventually achieved and, in fact, exceeded and these results were subsequently translated successfully on to the complete engine design.

Having achieved the required performance standards, the next phase was to carry out protracted endurance testing on the single-cylinder unit at the designed ratings to develop the piston assembly and cylinder liner up to a stage which would enable at least the guaranteed life between overhauls to be attained. This programme threw up some interesting problems.

At an early stage, experiments were carried out on various surfaces in the bore of the liner, a hard chrome surface lapped to produce a matt finish being decided upon, this being improved by dimpling by the "Honeychrome" process over the operating part of the cylinder wall. Activity was centred round the piston design.

A section through the original design of piston is shown in Fig. 1*a*.

The two members comprising the complete piston were machined from Y alloy forgings and these were secured together by bolts through the piston crown. The piston was oil cooled, oil being fed through a drilled hole in the connecting-rod into a collecting cavity in the piston and passing thence to the centre of the crown, through a series of radial grooves to the annulus behind the ring grooves from which space the oil escaped back to the engine crankcase. It will be noted that taper-sided gas rings are used and the efficiency of these may be judged from the fact that during the whole course of "Deltic" testing not a single case of a stuck gas ring has been experienced. The small end bearing in this piston was of needle roller type.

A number of troubles arose with this piston. Thermal cracks occurred at the securing bolt holes, the rate of wear on the top gas ring proved to be excessive, and wear in the groove of the top ring was also greater than was permissible. The two latter troubles were considered to be due to the fact that the temperatures at the ring grooves as recorded by fusible plugs were higher than could be expected to give good ring conditions. By a series of progressive steps the piston was therefore modified to produce the design shown in Fig. 1*b*. Here the securing bolts have been discarded and replaced by a spring circlip at the bottom of the piston. This proved to be quite satisfactory, it being remembered that in the two-stroke cycle there are no loads under running conditions tending to separate the two members.

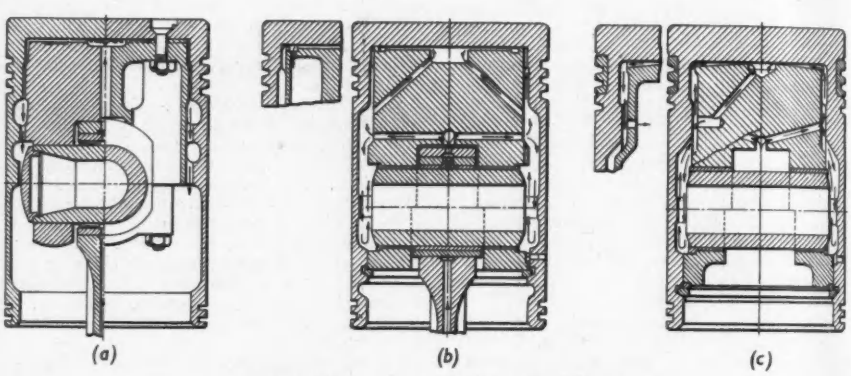


Fig. 1—First, second and third designs of piston

In addition to this change, the oil cooling system has now been altered, oil now being fed from the collecting cavity in the piston, transversely into a closed annular space extending from behind the ring grooves to the lower end of the skirt. The intention here was to use the oil as a mechanical aid to the natural conductivity of the piston material, it being shaken continuously from one end of the annulus to the other by the piston motion, picking up heat from behind the piston rings and releasing it at the cool end of the skirt. When the oil builds up to a certain level in this annulus it is able to escape through holes in the inner member to the centre of the crown and outward through radial grooves to the periphery where outlet holes are provided back to the crankcase, the crown cooling therefore being identical with that on the previous piston. These altered cooling arrangements exercised a very beneficial effect on the piston temperatures, the temperature at the top ring being reduced by 60 deg. Cent., the resulting figure being below that normally regarded as acceptable.

It will be noticed that the needle roller bearings have been replaced by a plain bearing, as the needle roller bearing had been found to suffer from occasional flaking on the gudgeon pin after extended periods of running.

With this piston a considerable improvement was seen in both piston ring and groove wear, although neither was regarded as entirely satisfactory. Before considering the further steps taken to deal with these difficulties it may be said that, although the general piston conditions were greatly improved with the design, it suffered from a somewhat serious defect in that after 500 to 1000 hours' running the small cooling grooves

across the underside of the crown became choked with carbon, this reducing the oil circulation and resulting in trouble from overheating.

Reverting now to the ring wear problem, it was observed that with this piston wear on the rings was concentrated over the arc of the ring which passed over the exhaust ports. Attention was therefore diverted to the liner design in this region and the number of ports was increased from seven to nine. Gothic type ports were first tried, as it was thought these would be kinder to the rings. This, however, proved to be erroneous, and as a slight loss in engine performance was involved with these ports a return was made to the rectangular shape.

This change in port configuration proved to be the complete answer to the ring wear problem. The groove wear, however, persisted and Fig. 2

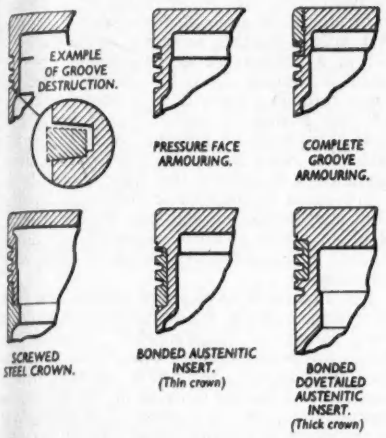

EXAMPLE OF GROOVE DESTRUCTION.
PRESSURE FACE ARMOURING.
COMPLETE GROOVE ARMOURING.
SCREWED STEEL CROWN.
BONDED AUSTENITIC INSERT. (Thin crown)
BONDED DOVETAILED AUSTENITIC INSERT. (Thick crown)

Fig. 2—Experiments to prevent groove wear

shows a number of methods which were tested in an effort to overcome this problem. Most of these introduced new difficulties of their own, but a satisfactory solution was eventually found by changing over to a cast aluminium outer member carrying an austenitic iron insert having approximately the same coefficient of expansion as the aluminium. This insert is cast into the piston body by the " Alfin " process, in which a coating of aluminium is applied to the insert before it is cast in, this enabling a chemical joint to be made and ensuring a satisfactory bond.

The final piston design resulting from the various considerations mentioned is shown in Fig. 1*c*. It will be seen that the cooling system has again been altered, the shake annulus now extending right across the underside of the crown from the outside. This piston has satisfactorily overcome all the difficulties to which attention has been drawn.

The development problems which have now been briefly considered, although confined to single-cylinder work, may be said to cover the major problems arising in the " Deltic " development programme. Fortunately, it was found possible to translate the results of this work successfully on to the complete engine, and while a number of troubles have presented themselves for solution on the engines themselves, these have been almost exclusively of a nature which arise in any mechanical contrivance, and solutions have been found by minor changes in design without the necessity for long exploratory programmes.

There were, of course, other interesting technical problems which were encountered, but time will not permit of their discussion here.

Six engines have been available for development testing and these had, by the time the engine was put into production, accumulated a total running time of about 10,000 hours, one engine having completed a test of 1000 hours' duration running on a cycle of a severe nature specified by the Admiralty. Two further engines have also completed a period of 2200 hours each in the seagoing test bed. In its now developed form the engine is well capable of satisfying the overhaul life requirements demanded of it and the general standard of reliability and freedom from wear of components is extremely high.

At this point it may be opportune to interpose some remarks on the general question of reliability of the high-speed engine of which the " Deltic " is an example.

It is often stated that the life and reliability of an engine of high rotational speeds must of necessity be poor compared with the low-speed engine, and this is sometimes regarded as axiomatic. All things being equal, it is undoubtedly true that higher rotational speed means increased wear and tear, but in fact at least as far as the " Deltic " is concerned, all things are not equal between the two types and the high-speed engine possesses important advantages from the wear and reliability point of view which are not open to the low-speed type. These advantages arise mainly from the greatly reduced sizes of components which are used in the high-speed engine and the consequent possibilities for the use of higher-grade materials and improved techniques in manufacture. To quote an example, the " Deltic " crankshafts are made in a high-tensile steel of 60 to 70 tons per square inch ultimate strength and are nitrided all over, which gives extreme hardness on the bearing surfaces. The bearings themselves are of thin-wall type lead bronzed lead plated and infused with indium. The results obtained from this combination are, to say the least, surprising, for after several thousands of hours of running no wear at all is detectable on the crankpins or journals, while the lead plating on the bearings, which starts its life 0·0005in thick, is still present over the whole bearing surfaces. Similar examples can be found throughout the whole engine construction and there is certainly no evidence from practical experience that the life of the " Deltic " should be lower than any other type of engine for equivalent piston ratings.

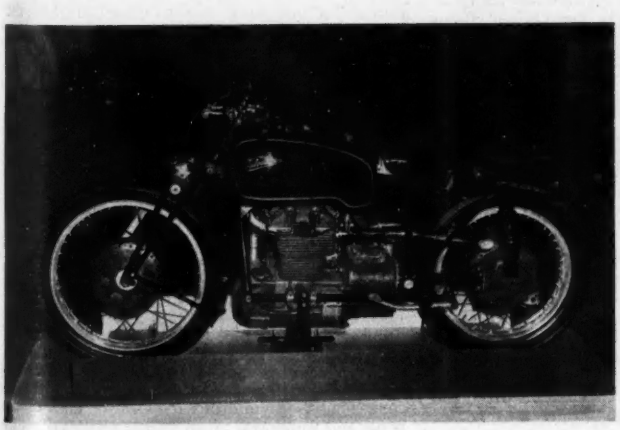
Motor-Cycle Show

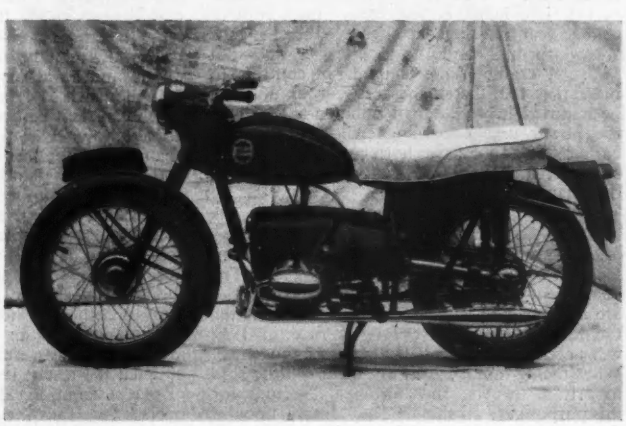
THE thirty-first International Cycle and Motor-Cycle Show opened at Earls Court, London, on Monday, the ceremony that was to have been performed by H.R.H. The Duchess of Gloucester on Saturday last having been cancelled as a result of a trade dispute.

The term " motor-cycle " includes, of course, cars with three wheels, scooters, and " mopeds " (auto-cycles). It is in the latter classes that activity is most marked at this year's show. For reasons obviously economic, there are now a number of three-wheeled cars, all smaller and lighter than the Morgan that some years ago was the only such vehicle offered in England. The Reliant is a revival of a pre-war vehicle and is now provided with bodywork of resin-bonded glass fibre, which clearly demonstrates how much less restricted is the design of articles for small quantity production in this material than in sheet metal. The Reliant, with an Austin " Seven " engine and Hotchkiss drive, is based very closely on four-wheel practice. In this it contrasts with the remaining three-wheelers, which obviously spring from motor-cycle inspiration. In all cases the trend on the Continent to use the air-cooled two-stroke for increasingly heavy duty is followed. The engines are closely related to motor-cycle units, possibly with reverse gears and self-starters, and, except on the A.C., drive one wheel only. Since the engines are vertical or slightly sloped, they are not easily accommodated, and the invariably severe problems affecting centre of gravity position in three-wheelers are thereby accentuated. The result of this approach to the three-wheeler is that the vehicles are of circumscribed performance. It cannot be expected that a design of real worth will emerge unless automobile principles as exemplified by Panhard and Volkswagen are emulated.

Possibly the most attractive of these little vehicles is the 200 c.c. Heinkel, which is described modestly as a cabin scooter. It is a remarkably compact enclosed conveyance for two passengers, and of obvious merit for use on congested roads ; so small is it that the left-hand drive might well not be a handicap in this country. Open cars, brilliantly styled, are shown by Bruetsch Cars England, Sherwin Road, Castle Boulevard, Nottingham, the larger versions being wide enough for three persons at the seat if not the toe-board. The smallest, only 5ft 8in long and 3ft wide, is the " Mopetta," with a 50 c.c., 2·5 h.p. engine on the sprung fork of the front wheel : it is steered by handlebars moving in the vertical plane. The German models on show, however, are ornamented in a manner disastrously reminiscent of showman's " Dodg'em " cars.

The scooter is now well established and includes such ambitious machines as the 200 c.c. Maico, which shares with the 350 c.c. horizontal single Guzzi that won this year's Junior T.T.,





Figs. 1 and 2—The 1939 supercharged 500 c.c. racing twin (left) shares with the new " Valiant " (right) such features as a welded tubular cradle frame, swinging rear fork enclosing the drive shaft, and full width hubs. The engine had geared crankshafts for perfect primary balance

the distinction of a windscreen mounted on the body. Both of these makes also provide excellent examples of the integral construction favoured on the Continent, with both crankcase and gearbox within a shapely nacelle that carries the rear fork pivots. The cylinder blocks are completely finned castings, including two 200 c.c. three-port cylinders on the German, and a 175 c.c. cylinder and the chain drive of the o.h. camshaft on the Italian.

The "mopeds" now include a number of machines which, in their attempts to resemble motor-cycles, have acquired riding positions in which it would be quite impossible to pedal them, and which are really toy motor-cycles: this is a result of the legal status of lightweights with pedalling gear on the Continent. While "moped" engines are predominantly two-strokes, like the power-assisted cycle units, an exception is afforded by the 60 c.c. O.H.V. Mercury, which develops 2·4 h.p. at 5200 r.p.m. and has the remarkable compression ratio of 6·5.

The motor-cycle proper is moving to meet these "lesser breeds" of machine, and fully sprung machines with such engines as the 98 c.c. Villiers are available at prices lower even than those of scooters. The light motor-cycle, however, is so essentially an assembly of proprietary components that many of them can hardly be identified.

But the true motor-cycle has not been submerged by the host of compromised vehicles that have been fostered by European poverty. Exhibited on the Triumph stand is the machine with which Mr. J. Allen (U.S.A.) established a world speed record of 214·4 m.p.h. It has an unsupercharged parallel twin engine of 650 c.c., mounted behind the driver in a long shell, a narrow oval in cross section, that encloses the machine completely. A fascinating study in the evolution of the motor-cycle is possible on the stand of Veloce, Ltd., where the supercharged 500 built in 1939 and used in practice on the Mountain Course that year is displayed. This machine is noteworthy for a parallel twin engine with contra-rotating crankshafts, both even torque and mechanical balance being sought by the designer. The engine is "square" at 68mm by 68mm. Shaft and bevel drive to the single overhead camshaft is used; the right-hand crankshaft drives the vane type supercharger, inducing through the carburetter and delivering to a long tract passing over the engine to the front of the block, and the left-hand shaft faces the gearbox. The final drive shaft runs within the swinging rear fork. The arrangement of the rear suspension, sprung by two telescopic units, the use of full-width hubs, and the welded frame are all features that have but recently become widely accepted. Torque tube drive for motor-cycles is associated particularly with Velocette, having been a feature of the silent, water-cooled, side-valve model. There has now been added to the range another air-cooled twin; this, the "Valiant," is based closely on the existing horizontally opposed power unit, but with enclosed push-rod O.H.V. has 60 per cent more power. Four instead of three gears are provided, the indirect ratios being 1·35, 1·83, 2·8. The right foot, instead of the right hand, is now called upon both to change gear and start the engine: the change is "down-for-up," and the kick-starter does not fold. A cradle frame is used—in contrast to the earlier 192, the engine and gearbox unit can be removed in a matter of minutes—and above the power unit a cowling encloses the single carburetter and electric horn: the fuel tank is separate, a few inches above, and quickly detachable.

The remarkable resemblance of the 1939 racing machine to to-day's production models draws attention to the dangers inherent in the abandonment of racing by British manufacturers. The constituent firms of Associated Motor Cycles are no longer to run factory teams, so that the Golden Jubilee Tourist Trophy race in 1957 will be contested by no British works machine. What racing motor-cycles are made will be sold to private owners, and "Manx" Nortons for this purpose are on show. The "International" does not appear, but an interesting mount that is as functional a machine as can well be visualised is that used by Mr. L. Archer to win the European Moto Cross championship. This has a modified "featherbed" frame carrying the cast magnesium crankcase of the racing engine, but crowned with the aluminium cylinder and single-camshaft head of an "International."

The two contrasting trends on the part of premier makers of the abandonment of racing and a concentration of engineering ability on sporting machines appear to indicate a policy of surviving on the presently accumulated knowledge, ability and successful development work. It is remarkable that the modern British environment of inadequate roads, scarce fuel and restricted capital has not caused the evolution of a monocar or of motor-cycles of a more utilitarian nature.

Deep Diving and Life-saving from Submarines

BY OUR NAVAL CORRESPONDENT

WHEN in the early 'thirties salvage was finally abandoned as a method of saving life from a sunken submarine, investigation had shown that by donning the Davis escape apparatus and breathing pure oxygen men still alive in a submarine at the bottom of the sea had a good chance of reaching the surface provided the depth was no more than about 200ft. Bulkheads in all submarines built subsequent to this time were accordingly strengthened to ensure that they would stand the pressure at that depth if a compartment were damaged and open to the sea. Further research has, however, proved that the main hazard is not the ascent, but the period during which the compartment is being flooded up to equalise pressure, and to enable the hatch to be opened. After some hours diving the air becomes foul from CO_2, which, if breathed for any length of time at a pressure equal to 150ft, is lethal. It was also found that breathing pure oxygen from the Davis escape apparatus (to avoid "bends," or diver's paralysis, resulting from a quick ascent to the surface after breathing the nitrogen in the air under pressure) introduces the no less serious danger of oxygen poisoning after a period of about five minutes. The method now adopted for saving life down to a depth of 200ft is therefore to make a "free" ascent, wearing only an immersion suit, after breathing a mixture of oxygen and nitrogen from bottles during the period the compartment is being flooded up. The bottles are built in at each end of the vessel and are fitted with a tube and mouthpiece for each man.

The hull of a submarine has, however, always been designed to withstand a greater pressure than 200ft to enable her to dive deep when being hunted by an anti-submarine vessel. The hulls of new submarines are, indeed, now being built to withstand the pressure at depths of 600ft and more, in view of the constantly growing effectiveness of anti-submarine detection and destruction devices. The Admiralty has therefore for some years been considering the possibility of saving life when men are trapped on the bottom at the greatest depth to which a submarine can dive—a problem which depends for its solution on the practicability of a diver being able to operate at that depth. Since the war the United States Navy has had available a rescue chamber or bell, which can be manipulated by a diver to plumb and be attached to the hatch of a submarine which is lying on an even keel. The hatch can then be opened and the trapped men are able to walk up from the submarine into the chamber, without having suffered the discomforts and dangers of flooding up and making a free ascent to the surface. Even so, however, the chances of survival are far less than if a free ascent were made from a depth of 200ft. The vessel must be lying approximately on an even keel and, above all, she has first to be located; though this can be assisted by the indicator buoys and underwater signal ejectors (for firing smoke candles) with which existing submarines are equipped. In any event the Admiralty has adopted the rescue bell as a practicable method of escape from any depth at which a diver can operate and all new submarines are to be equipped with an escape hatch at each end of the vessel fitted to take the bell. They are also to have their bulkheads strengthened to the full diving depth of the submarine, with air supply and exhaust connections at the bow and stern to enable the air to be refreshed while the rescue bell is arriving or in case operations have to be suspended due to the weather.

It is thus of highest importance that continued progress should be made in solving the problems still presented by deep diving. The Royal Navy has been investigating these problems over a long period and recently announced that a naval diver, equipped with a helmeted flexible diving suit and receiving a breathing mixture of oxygen and helium, reached a depth of 600ft in Norwegian waters. This must however be regarded in the nature of a freak dive from an operational viewpoint. A diver who has been on the bottom at 600ft for no longer than five minutes has to be "decompressed" under gradually reducing pressure, for five hours and thirty-eight minutes before finally being allowed to breathe air at atmosphere pressure. It is true that most of this time he spends not in the water but in a submersible decompression chamber which is lowered down to him and which he enters through a lower door at about 200ft, the chamber having an attendant and being kept clear of water by air pressure on the diving bell principle. None the less, for a practicable diving operation it is essential that there should be an improvement on the routine dives to a depth of 430ft now carried out with ease for a maximum of about twenty minutes, using an oxy-helium mixture (compared with a depth of 100ft when breathing air).

The mixture of oxygen and helium is a great improvement on air, but a diver using it at depth takes longer to "decompress" because the helium gas penetrates his tissues. The longer he stays down and the deeper he is, the more helium is absorbed. On the other hand, the mixture is superior to air for two reasons. The nitrogen in air produces a narcotic effect, which prevents the diver working at full efficiency in depths exceeding 240ft. Secondly, the oxygen content of air is such that it reaches a toxic pressure at just under 300ft; 300ft can thus be accepted as the outside safety limit for a diver using compressed air. There is no such limit for the oxy-helium mixture. Helium seems to have no narcotic effect whatever. If it exists at all, it is likely to be at a depth beyond that at which other limiting factors will intervene. The principal one at the present day, as already pointed out, is the decompression time. Oxygen poisoning is avoided by limiting the percentage of oxygen in the mixture. The mixture, incidentally, does not provide adequate oxygen until a certain depth is reached. A change over has to be made from air to mixture at a fixed level both in the descent and during the ascent, or the diver will suffer from lack of oxygen at shallower depths. The problem of "decompressing" in the shortest possible time without risk of "bends" is a complex one, particularly when using helium, and has not yet been solved. Encouraging results are, however, being obtained as the result of the research work now being done on this subject at the Royal Naval Physiological Laboratory, Alverstoke, Hants.

It is perhaps worth pointing out that the invention of the "aqualung" has in no way outdated the flexible suited helmet diver, whose operations are controlled by a surface vessel. The "aqualung" is purely a shallow diving apparatus. The French, who are the acknowledged experts in its use, maintain that none but an expert should venture with it below 200ft and the "fatal limit" is not far beyond 260ft. In other words, the deep diver begins roughly where the aqualung diver leaves off.

TWIN-DRILL RIGS FOR TRENCH BLASTING HOLES.—An order for eight special drill rigs for use in Saudi-Arabia has been placed with the Climax Rock Drill and Engineering Works, Ltd., Aldwych House, London, W.C.2. These rigs are intended for use in drilling shot blast holes for trenches being cut in rock for pipelines. Each twin-drill rig consists of a heavy inverted tubular U-shaped frame with a chain-feed drill carriage supported on each leg through cone clamps. A 4in drifter mounted on each cradle is fed and withdrawn by an endless chain driven by an air motor, and the cone clamp support enables a carriage to be swivelled through a wide angle for drilling inclined holes.

Expansion of Transformer and Rectifier Factory

ON September 26th we paid a visit to the works of Hackbridge and Hewittic Electric Company, Ltd., at Walton-on-Thames, Surrey, which this year celebrates its fiftieth anniversary. Since 1950 the company has undertaken a large programme of reconstruction and expansion. Much processing and testing equipment has been installed, mainly for the manufacture of very large high-voltage transformers such as are now required for the super-grid. In this connection must be mentioned the erection of a further extension to the works and installation of a specially designed transformer process oven and associated oil treatment plant. The impulse test laboratory has been increased in capacity and an annealing furnace is being installed for treatment of cold rolled steel. At the same time, a measure of expansion has taken place in almost every department. The factory roof has been reglazed and the interior completely repainted and rearranged to achieve better lighting, cleanliness and ease of production. The flooring of all factory extensions has been laid with ferro-granolithic material in order to give adequate strength to carry highly concentrated loads, with freedom from dust. In addition the whole of the unglazed portions of the roof and the side walls above the brick line throughout the factory have been lined with thermal insulation to facilitate the uniform heating of the shops in cold weather.

Particular importance has been attached to the manufacturing stages of very-high-voltage units and a portion of the extended No. 3 bay has been devoted exclusively to this assembly. It has been screened off and the floor specially painted to ensure that a high standard of cleanliness is maintained. Coil winding for these units is carried out in similarly painted and screened coil winding bays. Two 120MVA, 275kV transformers are at present in course of production in these departments.

The new extension forming No. 9 bay now in course of construction, measures 120ft wide by 105ft long and a second floor is provided over half of this area, giving a total extra floor space of 18,900 square feet. This section will be devoted almost exclusively to winding and erection of rectifier transformers.

The works boilers have been converted to oil-firing, thereby eliminating the dust associated with coal and ash handling. The plant consists of three boilers operating at 100 lb to 120 lb per square inch and is capable of raising 40,000 lb of steam per hour.

Oven and Impregnation Plant

For effective insulation it is essential to remove moisture and air from the transformer unit.

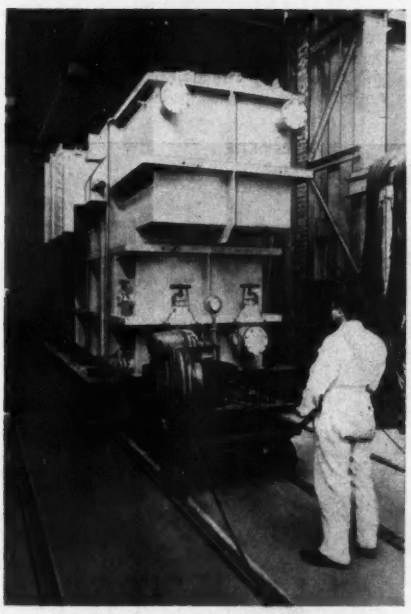


Fig. 1—Part of the drying oven showing a 45MVA transformer being removed on a hydraulic bogie

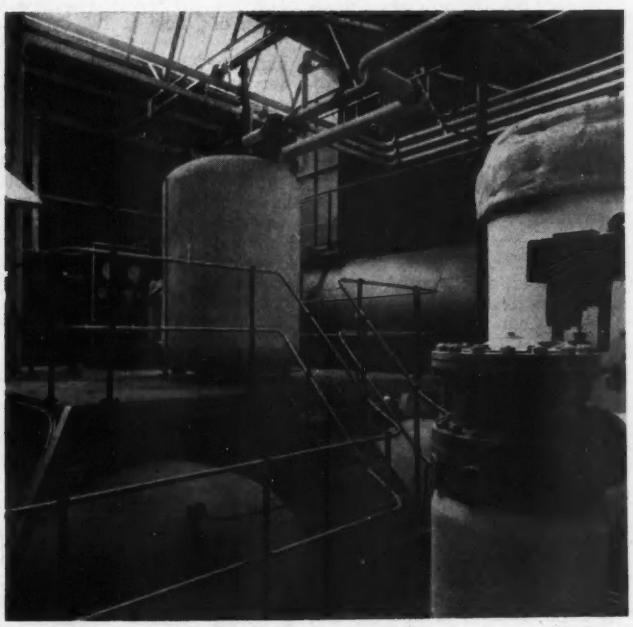
Similarly, the oil has to be dried, deaerated and filtered to remove all fibrous and suspended foreign matter, so that the maximum possible dielectric strength of the insulation materials may be achieved.

For this purpose an up-to-date process plant has been installed recently in collaboration with the General Engineering Company (Radcliffe), Ltd. It incorporates a drying oven (Fig. 1), which is capable of accommodating the largest transformers envisaged complete in their own tanks. The plant includes deaeration equipment for treatment of the oil prior to transformer impregnation and for subsequent recirculation, also ancillary gear and controls, together with automatic control of temperature for all process equipment.

This plant allows the drying-out of core and coil assemblies before impregnation. Units can be cooled off in a controlled atmosphere to permit transformer assembly personnel to enter and retighten the coils which shrink in the drying, thereby reducing to a minimum the time of exposure to the shop atmosphere. The required oil is deaerated and maintained in reservoirs in a heated condition under vacuum in readiness for use. Special attention has been paid to ease of transportation of units in and out of the oven, and on the shop floor, by means of hydraulic bogies which run on flush-mounted rails.

The equipment has been installed as a self-contained unit in close proximity to the heavy erection shop, e.h.v. power test department, impulse test laboratory and despatch exit, so that the work has to be moved as short a distance as possible from one section to another. By means of a 100-ton overhead crane, transformers for treatment are placed on the bogies and run into the oven, from there to the impulse test laboratory and back to the crane for loading on to the transport vehicle.

The Oven.—The oven chamber is 37ft 6in long, 26ft 6in wide and 24ft high. It is insulated with fibre glass on the walls and ceiling, and is lined with sheet aluminium. Good illumination is provided so as to facilitate assembly work. The chamber is closed by means of a sliding wall which is sealed in the closed position and incorporates inspection windows and a door. The main system of air ducts through which the circulating air from the blowers overhead (Fig. 2) is passed is arranged on both side walls to give a uniform distribution of temperature. Auxiliary air supplies, vacuum line and oil supply are connected by flexible hose from flanged connections inside the oven. Measuring and control instruments are mounted externally on a central control platform, and recording instruments include electronic devices for oil level indication and protective alarms.



Figs. 2 and 3 (Left)—The closed air circulation equipment above the oven. (Right) Oil storage and treatment plant showing centralised electrical controls, deaerator and filter presses. Underneath the platform may be seen one of the two storage tanks

Oil Plant.—The oil is stored in three tanks, each of 10,000 gallons capacity, one for raw oil as received from the suppliers and two for storing treated oil. The oil is fed from the receiver tank to the storage tanks through a filter and calorifier, and when the required quantity of oil has been transferred it is circulated through the filter press and calorifier, and passed through a heated deaerator, where it is atomised under high vacuum to expose the maximum surface area for extraction of moisture and air until the highest possible dielectric strength has been reached. A sufficient quantity of treated oil is held in readiness for any requirement. One of the two storage tanks may be seen in Fig. 3.

The vacuum plant comprises three pumps of the gas ballast type (Fig. 4), which are connected so as to enable vacuum to be drawn either independently or collectively on the oil reservoirs, deaerator, or transformer under treatment. A water-cooled condenser is incorporated in the vacuum lines for the extraction and measurement of water and collection of gas condensate. Its use makes the pumps more efficient and provides an indication as to progress of treatment.

Drying Treatment.—After bringing the core and coils assembly into the drying oven, air heated by means of external steam/air heat exchangers is circulated through the system of ducts and the temperature in the oven raised to 105 deg. Cent. The steam heating is automatically adjusted to control the speed of evaporation, which is important if deterioration of the insulation and the rusting of metal parts and cores is to be avoided. To prevent a progressive rise of relative humidity a proportion of the moisture-laden air is allowed to escape into the external atmosphere and is replaced by an equivalent intake of filtered air. Temperature, dispersion factor and insulation resistance, also per cent relative humidity in the oven and the factory are recorded continuously, and these, after approximately twenty-four hours, combine to indicate that the bulk of the moisture content has been removed and that the next stage of drying should commence.

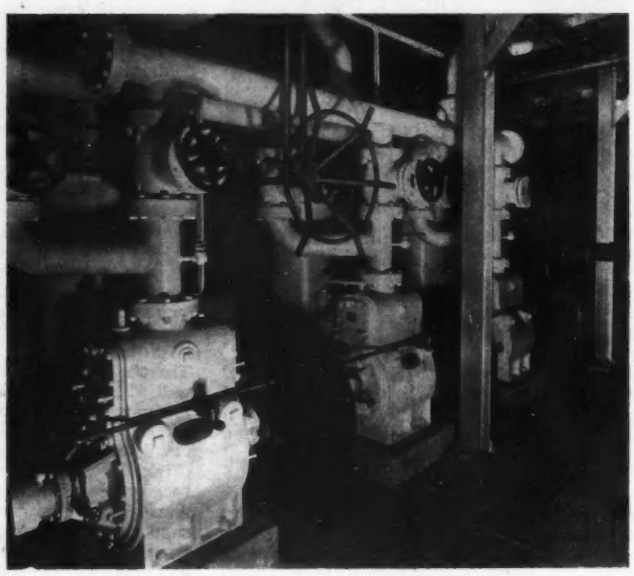


Fig. 4—The vacuum pumping equipment

During this next stage the relative humidity of the oven is gradually reduced to a very low dew point equivalent to vapour pressure of approximately 0·5mm Hg absolute. This is done by replacing the atmosphere in the oven with dry air by closing the air intake dampers to the oven, and bringing into operation the main air circulating system. This system gives 20,000 cubic feet per minute and is boosted by a secondary air stream at 2000 cubic feet per minute. The proportion of dry air is increased, while a corresponding amount of air is allowed to escape to atmosphere. All the time, a temperature of 105 deg. Cent. is maintained. For obtaining a supply of dry air, two absorption towers are used alternately on an automatically controlled cycle, so that whilst one is in service the other is being reactivated. About seventy-two hours are required to complete a preliminary treatment. After cooling off in a controlled atmosphere, and tightening of the coil clamping bars, the unit is removed from the oven and quickly placed in its tank, then returned to the oven, connected to the external process plant by means of flexible hose, and sealed.

It is then processed by alternately applying a vacuum and a flow of air within an enclosed system. By heating the circulating air inside and outside the transformer its temperature is raised to 70 deg. Cent. In order to reduce the humidity, a dry air stream is injected into the air flow within the tank and a corresponding quantity of air allowed to escape. When finally a vacuum of 0·1mm Hg absolute has been reached, a quantity of deaerated oil is added from the storage tank sufficient to ensure impregnation of all the insulating materials, and to fill the transformer tank to a predetermined level. An important characteristic of deaerated oil is its avidity for air, and this is particularly advantageous at this stage of treatment since it tends to search out any traces of air which may have remained in the insulating materials before impregnation.

The space above oil level in the tank is now returned to atmospheric pressure from a dry air supply and the transformer rapidly cooled, using air circulating facilities within the oven. Internal circulation of oil within the tank as a result of cooling accelerates re-absorption of air into the oil at surface level until it has regained its normal quota, but the procedure here described ensures that only dry air is re-absorbed. After cooling the transformer is withdrawn from the oven for assembly of bushings and other auxiliary fittings.

The last stages of treatment are now performed outside the oven by means of flexible connections to an associated service point. Any moisture which may have been absorbed while bushings, &c., were fitted is eliminated by means of dry air flow at 105 deg. Cent. after which the transformer is connected to the treated oil reservoir and the oil raised under vacuum to the correct level. Finally, the oil is pumped round a circuit comprising the transformer (now under the pressure of a head of oil), the filtration plant, calorifier and deaerator until it has regained its original degassed state, and the mature electrical strength of the insulating materials is obtained. At the same time, any fibrous material from the core and windings which may have become suspended in the oil following impregnation will have been removed.

Surge Generator Equipment

The surge generator equipment has been transferred to more spacious quarters in the extended No. 5 bay. Its nominal voltage has been increased to over 2,000,000 V for impulse tests on transformers up to the 400kV class.

The generator comprises twelve stages, each consisting of an oil-filled capacitor with the usual front, tail and charging resistors and adjustable gaps. The twelve gaps are adjusted simultaneously by a small geared-down electric motor which is operated from the control desk. The gap spacing control is calibrated direct in kilovolts, and adjustments can be made while the capacitors are being charged up.

The step-up transformer has a peak voltage of 100kV at 50 c/s and a voltage doubling selenium rectifier system gives the 175kV d.c. for charging the twelve sections of the generator in parallel, this being the maximum permissible working voltage. When the system is triggered all the gaps spark over the capacitors being placed temporarily in series, giving a peak of up to 2·1 million volts, depending on the gap setting. At the same moment an impulse is transmitted to the oscillograph and the "X" sweep is released to make the photographic record.

Facilities are included for the rapid developing and examination of oscillograms while a series of tests is being carried out.

A recurrent surge oscillograph which enables the surge distribution and other data of the windings to be ascertained has been produced by the company's research laboratories. This apparatus gives a valuable prediction of the impulse distribution and assists in locating any weakness which might be prejudicial to the success of the full-scale test.

The equipment comprises an electronic surge generator and an oscillograph mounted as one unit. The recurrent surge is generated at 150V or 300V, 50 c/s, and can be seen as a steady record on the viewing screen of the cathode ray oscillograph, where it can be photographically recorded. In addition, the equipment can produce a "chopped wave" to simulate the most stringent part of the full impulse test. The oscillograph is provided with timing waves, and a range of sweep speeds between 0·5 and 150 microseconds, and the generator can easily be adjusted to produce any desired wave form.

Annealing Furnace

A considerable proportion of the company's output of transformers consists of units in which cold-rolled steel is used for the core. Experience has shown that the ideal performance of the steel can be achieved only after "work stresses" produced in its grain structure during fabrication of the laminations have been relieved.

To meet this requirement an "EFCO" annealing furnace is being installed in bay No. 3. This furnace will permit the stress relieving of 20 tons of steel per week at a maximum temperature of 850 deg. Cent. in a controlled atmosphere of nitrogen.

The plant comprises two electrically heated hearths, each capable of accommodating a charge of 5 tons of maximum size, a muffle for holding each charge in the nitrogen atmosphere, an electrically heated bell, and a cooling hood.

Continuous operation is obtained by alternate charging of the two hearths and transferring the furnace bell from one stack of sheets to the other. Temperature programme control equipment has been fitted to the bell and the two bases, and in addition provision is made for recording check temperature tests of the actual charge being treated. The controlled atmosphere is obtained from a cracked and burnt ammonia plant comprising a burner, a cracker with catalyst, a katharometer with flow meter, for determining the gas composition and flow, and an activated alumina gas drier with automatic change-over.

Rectifier Manufacture

The recent extensions have permitted the opening of a complete new assembly bay for large power rectifiers and rearrangement of the medium and low power sections. The rectifiers are constructed on a unit basis and modern production methods have been introduced to speed up assembly and despatch.

Oil Mist Precipitator for Machine Shops.—An equipment known as the "Trion" oil mist precipitator which has been introduced into this country by W. C. Holmes and Co., Ltd., Huddersfield, is designed to prevent the coolant oil mist produced in machining metals from contaminating the atmosphere. It operates on the electrostatic principle: the oil mist or smoke is drawn from the machining point through ducts into a collecting cell. In this cell the oil and smoke particles receive a positive electrical charge as they pass through a high-voltage ionising screen. These particles are then attracted and adhere to the collecting plates, which form the negative elements of an electrostatic field set up between a series of parallel plates, electrically charged alternately positive and negative. The collected droplets agglomerate on the plates and as the accumulation builds up the oil drains off into a collecting basin for ultimate re-use.

Fibre Blending and Carpet Plant

As part of the plan to expand the production of needle-loom carpets, Petmar Industries, Ltd., has built a fibre blending and drying plant which is semi-continuous in operation and is capable of handling 3500 lb of material each hour.

ON Tuesday, September 18th, the new blending plant at the Greenhill Mills, Batley, of Petmar Industries, Ltd., was officially opened by Lord Swinton in the presence of a large number of guests. In welcoming Lord Swinton, Mr. Marbach gave a brief review of the history of the company (which was founded ten years ago) and its products, and outlined developments leading up to the installation of plant to produce needle-loom carpet. He went on to mention that further development was planned and that the opening of the new dyeing and blending plant and warehouse marked the completion of the first stage of the expansion programme.

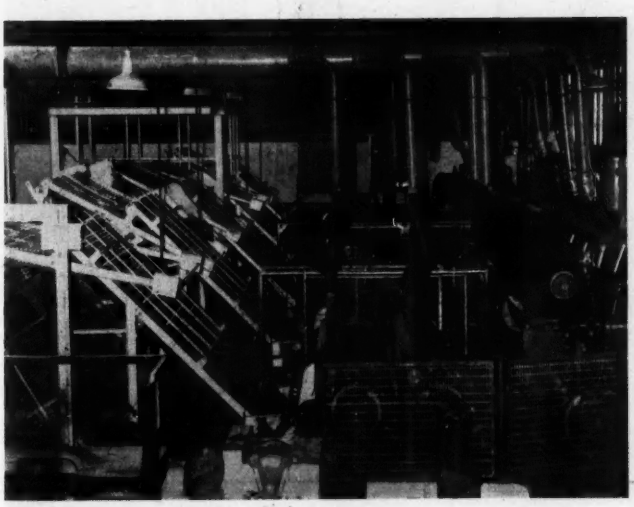
The warehouse measures 578ft in length by 50ft wide by 24ft to the eaves, and replaces five other warehouses by housing the entire stock of carpets. Despatch and handling will be improved when the mechanical handling and special racking equipment are installed. A brick structure 300ft long by 93ft wide by 26ft high from ground to eaves, houses the blending plant, which has been designed to blend 500,000 lb of fibre in a three-shift, seven-day week. The architects were Messrs. Howarth Walker and Liley, and the installation includes a squeezing press, opening and drying machines, supplied by Petrie and McNaught, Ltd., and a blending plant provided by Spencer and Halstead, Ltd. Cliffe and Co., Ltd., was responsible for the hopper feeding machines, and the Patent Automatic Machine Feeding Company, Ltd., for the feeding machine, while the "Fearnaughts" were manufactured by Walker and Smith (Batley) Ltd., and Wilson Knowles and Sons. The Garnett machines were manufactured by P. and C. Garnett, Ltd., and the electrical equipment includes switchgear and a transformer supplied by the Brush Electrical Engineering Company, Ltd., motors manufactured by the English Electric Company, Ltd., mimic panels by Gent and Co., Ltd., and starters by Brookhirst Switchgear, Ltd.

Drying and blending plant, showing both dryers and some of the storage bins

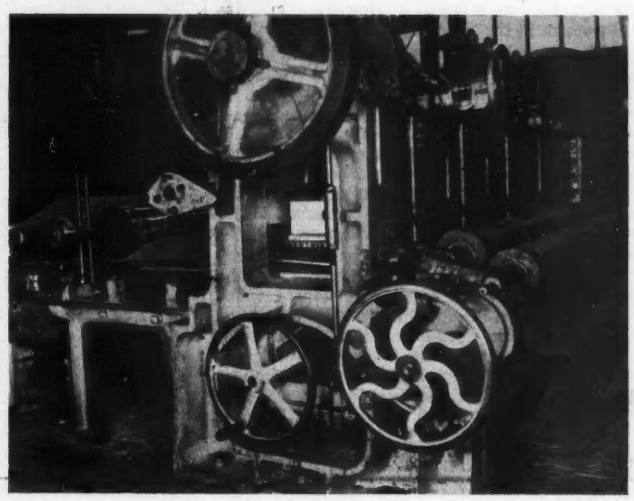
From the dye house, which is equipped with high-pressure, high-capacity dyeing plant, the wet freshly dyed fibres are transferred by overhead conveyor to the blending building, and deposited in an overhead bunker, ready to be processed. The fibre is delivered by an automatic hopper feeder, consisting of a creeper sheet and a spiked sheet and fitted with a mechanically adjustable beater, to the squeezing press. Even distribution of fibre across the feeder sheet is ensured by the action of the beater, which also controls the amount of fibre entering the press. Here most of the free water is removed by passing the fibre between two rollers, of which the upper one is rubber covered and pressed down by lever arms, operated by compressed air cylinders, to exert a pressure of about 15 tons per square inch. A stripper removes excess fibre from the roller so that no high-pressure points are set up during the operation. Another feeder moves the material after squeezing, to an opening machine, where the matted fibres are opened up, by a series of spiked rollers, before being delivered by an automatic feeding machine to the first of two dryers. All the units up to this point have individual drives, incorporating variable-speed gears, so that each can be adjusted to deal with different fibres and synchronised with each other.

A perforated slat conveyor passes the fibre through the No. 1 dryer, about 85ft in length, which is built in fourteen sections, each having a fan for circulating hot air. This air is warmed by passing over steam coils which are supplied with steam at a pressure of 65 lb/70 lb per square inch and at a rate of 7000 lb to 8000 lb per hour. Condensate from the coils is used to heat other parts of the building and the moisture-laden air is discharged to atmosphere by an extractor fan. A chain and lath cross conveyor turns the fibre over and delivers it to a second drying unit where the material is finally dried and conditioned to the correct moisture content. Some 3500 lb of dried material can be delivered per hour by the plant. Our illustration of the drying and blending plant shows, on the right, the feeders, squeezing press and opening machine leading to No. 1 dryer. In the centre is No. 2 dryer, and on the left can be seen some of the main storage bins. To minimise the risk of fire a drencher system, connected to the water main, is fitted to both dryers in addition to the automatic sprinkler system, which has been installed throughout the building.

The dried material is delivered to a hopper from which it is drawn by a high-velocity fan and injected, depending upon the quality of the fibre, either into a cyclone for dust removal or into overhead ducting for delivery to a set of storage bins. These bins are eight in number, of which four are available to receive the dried fibre at any one time, the other four being in the process of supplying fibre for blending. A certain proportion of the fibre is directed to the battery of Garnett machines for treatment before blending, and returned to one of the bins. Fibres of the quality required and to the amount required by specification are placed in a weighing machine, supplied by the Dial Automatic Scale Company, Ltd., which deals with the fibre in 200 lb lots, and is fitted with a base consisting of an endless belt conveyor. This discharges the complete load to an underground hopper

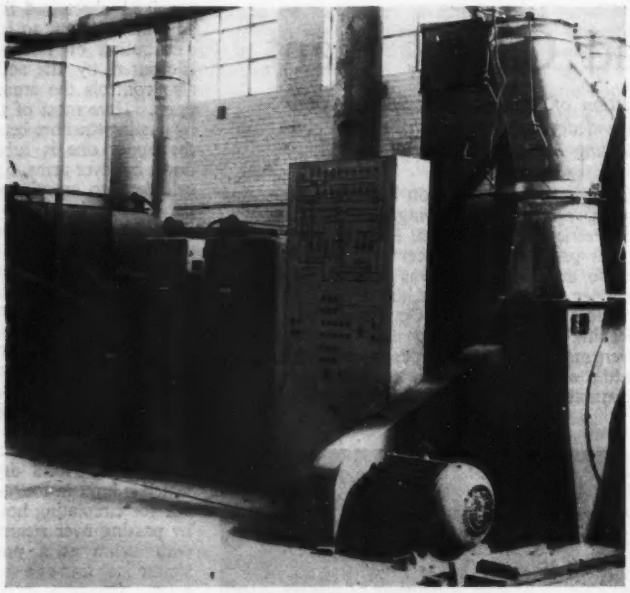


Battery of Garnett and other machines supplying fibre to the continuous carpet machine



Needle-loom carpet machine showing the hessian and fibre being fed into the machine and emerging as needled felt

feed machine from where it is delivered by fan first to a "centri-blender," where a preliminary opening up of the fibre takes place and some dust is removed, and then via a hopper to a "Fearnaught" machine, which also opens up the fibre and gives it a preliminary mix. From the "Fearnaught" machine the partially blended material is ducted to one of nineteen storage bins, which it enters at the top through a spinner, a device which is rotated by the reaction of the delivery air and which ensures even distribution in the bin. Each bin has a diameter of approximately 19ft and a capacity of about 8000 lb to 12,000 lb, according to the fibre being blended.



Third mimic panel of the "Melange" blending plant

For final blending the material is drawn through under floor pneumatic conveyor ducting to "centri-blenders," hoppers and "Fearnaught" machines and is delivered to a sheeting-machine, where it is baled ready for transport. This is only a temporary arrangement since it is planned to transfer the blended fibre through outside ducts, fitted with booster points, to bunkers at the carpet production lines. The final blend can, if required, be returned to main storage for reblending or delivered to a battery of six bins which have been provided for the preparation of mottled carpet material or "melange." The fibre is transferred from point to point by means of galvanised iron ducting, mainly 15in and 18in in diameter, through which it is blown by fans at a speed of about 3500ft to 4000ft per minute.

Control of plant operations is through three electric panels which includes relays and limit switches. A mimic panel A controls the squeezing and drying plant and provides for the starting of motors in correct sequence and indicates whether the various duct switches are correctly set. This checks whether the material is passing through in correct sequence, a point of considerable importance since the fibre is largely invisible until discharged to bin, while red and yellow lamps, respectively, indicate when a bin is full or is being emptied. All the machinery dealing with the fibre after it is weighed and is being blended is under the control of the mimic panel B, which also indicates which of the main storage bins is being supplied. The third mimic panel, C, and seen in our illustration, controls the motors driving the machines carrying out the final blend; lamps indicate from which of the main storage bins the material is being drawn and also movement in the "melange" section.

The research department of Petmar Industries, Ltd., carries out a considerable amount of work connected with future development as well as routine testing of current products. For wear tests special abrasion machines have been built, and the work has been supplemented by practical service tests. Colour and resistance to fading are carefully checked and wash-fastness determined, together with experiments concerned with resistance to insect attack.

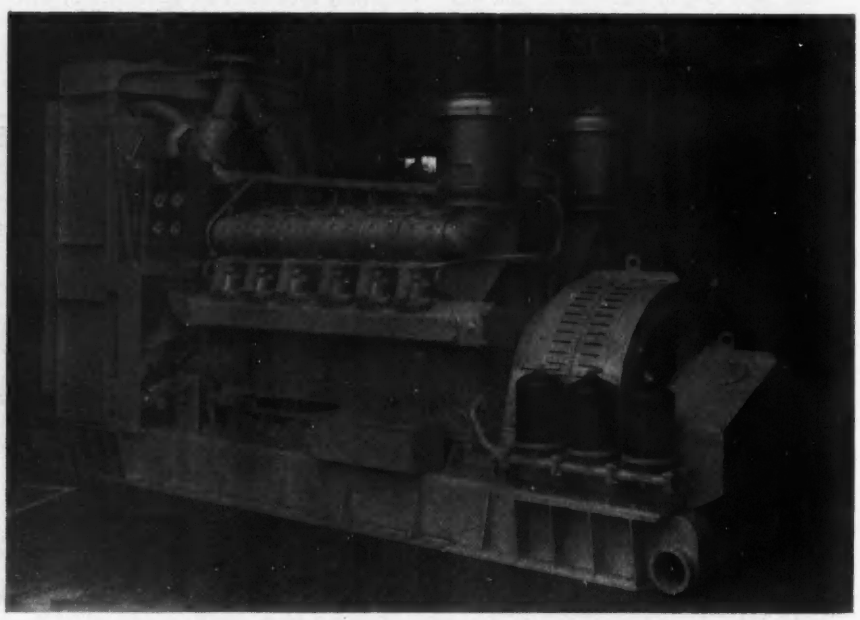
At the Greenhill Mills the opportunity was taken to see the fibre being used in the making of "Raymar" and "Velmar" carpets. In the manufacture of the needle-loom carpet the nylon reinforced fibre is supplied by five automatic feeding machines fitted with weighing devices to a similar number of Garnett machines. These deliver to a camel back lapper, which in turn delivers to a take-off machine, and the blend is fed in gossamer form to the needle-loom machine manufactured by William Bywater, Ltd. One of our illustrations shows the five sets of machines supplying fibre to the carpet loom. Hessian is laid in traverse in this machine, and as it passes through, synthetic fibres are continuously laid on it by the five sets of supply lines. At the first stage the base blend is delivered and at the second and third stages the middle blend, the top blend being laid on at the fourth and fifth stages. Beginning at the second stage, the blend at each stage contains an increasing amount of nylon fibre until at the fifth the nylon content is very large. In passing through the five stages about thirty to forty layers of fibres are placed on the hessian, which then passes over a floating beam and under a roller to control the flow of the material to the needleloom. Here, as seen from one of the illustrations, the fibre layers are pressed into the hessian by a plate fitted with approximately 6600 needles, each having nine barbs, which punch through the fibre layers and loop the fibres into the hessian. The carpet passes through a spray booth, where chemicals are sprayed on the top surface, and then on to an infra-red drying oven. In a semi-dried condition the carpet returns over a back roller to a second booth, where the back is chemically sprayed and then dried in an infra-red oven to complete the sealing of the fibres. Rubber backing is applied and the carpet passes through a hot air box and over a return roller, then is cooled in a stream of cold air before passing through nip rollers and a measuring device to a batching machine.

In another section of the plant a tufted form of carpet was being manufactured, and here trifold yarns, spun by an associated company, are drawn from creels, mounted on a framework, through small-bore tubing to the needles of a carpet loom. Here the yarn is tufted on to 12-oz hessian to give a density of 14,400 tufts to the square foot. After inspection the carpet is placed in a backing machine, where a viscous form of P.V.C. is applied, to seal the loose loops, and then dried in an infra-red oven.

Oil Well Drilling Package Units

For a number of years Davey, Paxman and Co., Ltd., has been supplying engines for powering oil well drilling rigs and these units, constructed as "package" sets, have been designed with the co-operation of the operators. Throughout this period the company has kept closely in touch with those responsible for operating the engines, so that extensive operational data and practical running experience covering every kind of site and a wide range of climatic conditions are available to the company. Based on this experience, Davey, Paxman and Co., Ltd., has introduced a new range of standardised oil well drilling package sets to which has been given the name "Drilpak." We recently visited the works at Colchester to see some of these sets under construction.

The power unit is the Paxman "RPH" engine, which is a vee-form, four-stroke engine having a bore of 7in by a stroke of 7·75in, and there are seven sets in the "Drilpak" series, which includes five powered by four-, six-, eight-, twelve- and sixteen-cylinder "RPH" engines, also two powered by twelve- and sixteen-cylinder, pressure-charged "YHX" engines. These engines have been designed so that wherever possible, wearing parts can be examined, adjustments made or replacements effected without dismantling other parts of the engine unaffected by maintenance requirements. The sizes of the engines listed provide an output ranging from 128 to 800 continuous shaft horsepower and the standard set, an example of which can be seen in our illustration, incorporates hydraulic coupling transmission, but provision is made for torque converter transmission. The former is a "Vulcan Sinclair" scoop-controlled, Mark SCR 5, hydraulic coupling, manufactured by the Fluidrive Engineering Company, Ltd., of a size suitable for the power to be transmitted and fitted complete with oil cooler. The latter has been developed in collaboration with the Brockhouse Engineering Company, Ltd., and



"Drilpak" 400 with "12RPH" engine and fluid coupling

"Drilpak" type	Engine type	Maximum torque (lb-ft) at output shaft speed (r.p.m.)	Continuous shaft horsepower at various speeds			
			900 r.p.m.	1000 r.p.m.	1100 r.p.m.	1200 r.p.m.
100	4RPH	640 at 750	100	110	120	128
200	6RPH	960 at 750	150	166	183	200
300	8RPH	1280 at 750	200	222	243	265
400	12RPH	1920 at 750	300	333	367	400
500	16RPH	2560 at 750	400	444	490	533
700	12YHX	2840 at 700	450	500	550	600
800	16YHX	3785 at 700	600	667	733	800

is fitted with an integral oil cooling radiator. However, the company can arrange to fit other makes of torque converter with suitable characteristics.

Constructional simplicity forms a fundamental part of the design with a view to ensuring the minimum of maintenance. The underbase is of robust welded construction, using rolled steel plate, which incorporates all pipe connections, so that external piping is eliminated and the piping is positioned so that it is given maximum protection. With all the engines having a common bore and stroke, approximately 70 per cent of the components are interchangeable and that, in turn, means that the spares required are kept to a minimum. The spares are packed according to whether they are destined for the home market or are to be sent by air, when the storage period is expected to be of short duration, or are intended for long-period storage in tropical countries. For tropical packing the component, after degreasing, is covered with a hot dip strippable coating which incorporates a small quantity of oil. This is deposited on the surface of the spare part so that when the protective coating is removed the spare is ready to be fitted.

The four, six and eight-cylinder engines have air starter valves, one per cylinder, while the twelve and sixteen-cylinder power units have an air starter motor. This is supplied with air at 250 lb to 300 lb per square inch and it is understood that a motor using air at 100 lb to 125 lb per square inch is being developed. Water-cooled exhaust manifolds are fitted to the twelve and sixteen-cylinder RPH engines, the remainder having dry pattern. There is a "Vokes" duplex oil fuel filter and inverted quick servicing pattern filters, with expendable elements, for the lubricating oil. A crankcase breather filter prevents entry into the crankcase should a vacuum be created. The radiator has hand-operated louvres and fan driven by "Fenner" anti-static endless vee belts. A flexibly mounted instrument panel records exhaust, water and lubricating oil temperatures, also lubricating oil and fuel oil pressures. The above table gives the range and output for sets fitted with fluid couplings.

The shaft mean effective pressure for the RPH engines is 76·5 lb per square inch, while that for the YHX engines is 117 lb per square inch, and the respective compression ratios are 17·25 and 14·25 to 1. Fuel injection pressures are respectively 1800 lb and 3000 lb per square inch, the normally aspirated engines having two valve cylinder heads and single hole pintle pattern fuel injector nozzles, while the pressure-charged engines have four valve cylinder heads and multi-hole fuel injectors. Ratings for the matched torque converter power packs are set out in the accompanying table :—

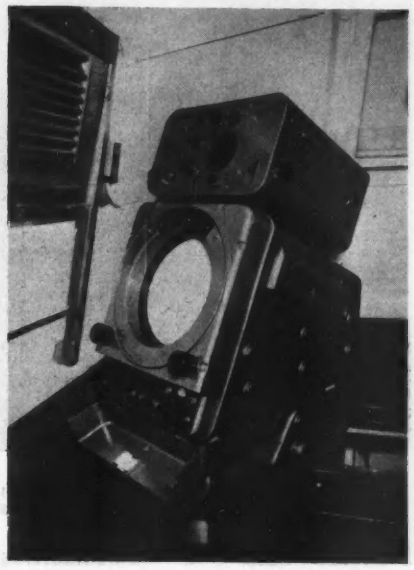
Engine type	Maximum power input to torque converter	Maximum governed speed, r.p.m.	Maximum lb-ft torque	Full load engine speed range, r.p.m.
4RPH	140	1,200	1,700	1,040–1,200
6RPH	210	1,215	2,580	1,080–1,215
8RPH	310	1,410	3,400	1,250–1,410
12RPH	425	1,250	5,180	945–1,250
16RPH	580	1,265	6,840	1,100–1,265
12YHX	700	1,360	7,800	1,180–1,360
16YHX	930	1,320	10,600	1,170–1,320

It is estimated that the service life of the engines is between 10,000 and 12,000 hours before they lose "tune" and require a major overhaul. Sets can be mounted on lorries, and if required engines embodying light alloy components can be supplied. Three gas "package" sets covering the range of 200 to 535 continuous shaft horsepower, are available, and for oilfield electricity generation there are self-contained generating sets incorporating diesel power units identical with those mounted in the "package" sets.

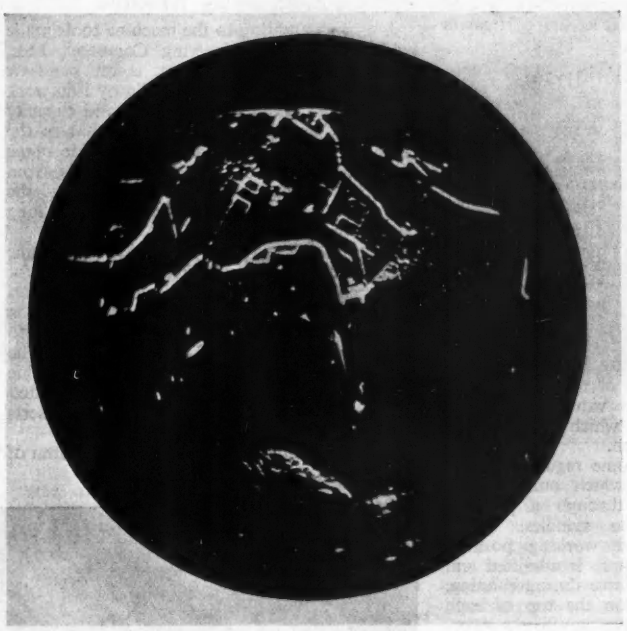
True Motion Radar

LAST month marked the culmination of many years of careful research into the use of radar at sea and intensive development by the technical staff of Decca Radar, Ltd., with the introduction by the company of the Decca true motion radar, "T.M.46." This is not a radar set which embodies improvements to previous models, but an entirely new system of marine radar presentation which introduces a revolutionary development in the use of radar at sea. During the years since radar was introduced advances in technique have enabled the equipment to give improved performance, better picture quality and greater reliability. However, the picture presentation has remained the same—that is to say, the display indicates the relative or apparent motion of all targets in relation to each other with "own ship" constantly positioned in the centre of the screen. The "T.M.36" differs from this in that it shows directly on the cathode-ray tube the true course and bearing of all targets, instantaneously and without plotting, which is completely the reverse of the conventional relative movement display. This means that "own ship" travels across the face of the screen with all other targets moving with their proper or true motion, course and speed, while all stationary targets such as buoys, light vessels, landmarks, &c., can be clearly seen to be stationary. By this technique the navigator has an automatically produced true plot of all details seen by his radar without delay and without any possibility of human error. The photographs which we reproduce show the "T.M.46" "Display and Trackmaster" unit and a true motion plan position indicator (P.P.I.) plot. The set has a range of 45 miles and two pulse lengths, 0·1 microsecond for high definition at short ranges, and 1·0 microsecond for detection at long range.

Controversies have developed during recent years regarding the use and interpretation of radar at sea. The latter involves plotting in order to determine the true course and speed of other vessels before any action, necessary to avoid collision, may be taken. All this is avoided by the "T.M.46" radar, as it presents an instantaneous and unambiguous picture of true motion. The display of true motion is obtained by feeding compass and speed information into a small resolver in the "Trackmaster" unit, mounted on the viewing unit. Here the speed and direction are converted into east–west and north–south movements which control the current in the off-centring coils of the display and so affect the position of the electrical centre or "own ship" position. On a compass stabilised display the electrical centre moves in harmony with the ship's course and speed, and so presents true motion or a bird's-eye view of the situation. Speed is fed into the "Trackmaster" manually or automatically from the ship's log and must be reasonably accurate. Afterglow trails behind other ships' echoes provide for the estimation of their course and speed, aided by a mechanical cursor.

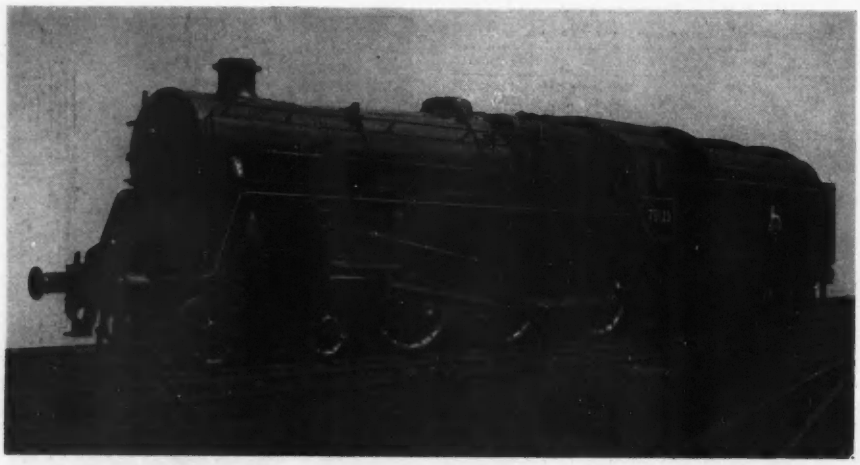


Model "T.M.46" display and "Trackmaster" unit



Reproduction of true motion display of part of the River Schelde. Channel buoys are shown stationary and the true course of other ships is shown

Facilities are provided to read both range and bearing regardless of the position of "own ship" on the face of the P.P.I. Range rings and a variable range marker appear as concentric circles around "own ship" and an electronic bearing marker, which appears as a radial electronic line centred on "own ship," measures the bearings, read from a calibrated dial, of other vessels irrespective of the position of "own ship." The movement of the electrical centre over the face of the tube in the direction of the ship's course eventually reduces the ahead warning range so that it is necessary at intervals, depending upon range scale used and speed of ship, to reset "own ship" position. This is effected by north–south and east–west shift controls to any desired position on the screen and the true motion picture is again developed almost instantaneously. The display may be operated to show either a conventional "ship's head up" picture, a conventional compass stabilised picture or a true motion picture.



Class "5" mixed-traffic locomotive fitted with British-Caprotti valve gear. Thirty of these two-cylinder locomotives have been built for service on British Railways

Standard Class "5" Locomotives with British-Caprotti Valve Gear

BRITISH RAILWAYS recently completed thirty locomotives of the class "5" mixed traffic type fitted with British-Caprotti valve gear for service on the London, Midland, Western and Scottish Regions. The first standard locomotive fitted with this design of valve gear was the class "8" three-cylinder, 4–6–2 express locomotive "Duke of Gloucester," described in our issue of June 4, 1954. The class "5" locomotives just built are generally similar to the other standard locomotives of the class, except that the Walschaerts gear has been replaced by that of British-Caprotti design. Their leading particulars are given in the table below.

Cylinders (two) diameter and stroke	19in by 28in
Wheel diameters :	
Bogie	3ft
Coupled	6ft 2in
Tender	3ft 3½in
Wheelbase :	
Coupled	15ft 6in
Engine and tender, total	52ft 1in
Boiler pressure	225 lb per square inch
Heating surfaces :	
Tubes	1479 square feet
Firebox	171 square feet
Total evaporative	1650 square feet
Superheater	358 square feet
Grate area	28·7 square feet
Tractive effort	26,120 lb
Weight in working order :	
Engine	76 tons
Tender	51 tons 5 cwt
Total	127 tons 5 cwt

In these locomotives separate inlet and exhaust poppet valves at each end of the cylinders are actuated by cams, each valve being contained within a cage into which the valve is pushed by the cam to open.

The main locomotive dome regulator incorporates a special valve which automatically admits saturated steam through a pipe to the bottom of the valve spindles. This lifts the valves into their working position before the main steam supply is admitted and also provides the closing force during running. The cam boxes situated on the top of each cylinder to control the valve movements incorporate all the improvements developed as a result of experience gained from former L.M.S. locomotives in service which are fitted with this valve gear. The drive for the cam boxes is taken from the intermediate coupled wheels by a worm gearbox mounted on each return crank, and tubular shafts transmit the drive from the gearboxes to the cam boxes.

The reversing wheel in the cab is connected by a transmission tube to a "self-locking" worm reversing gearbox on the left-hand side of the engine. A reversing shaft with "Layrub" flexible couplings connects across the engine to the right-hand worm reversing gearbox. Reversing the locomotive is done by advancing or retarding the angular position of the cams relative to the camshafts and any cut-off desired is obtained by the angular adjustment of the inlet cams in relation to each other.

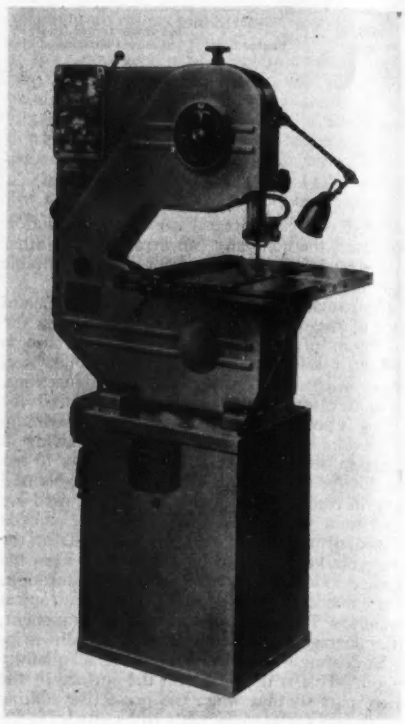
One of the new locomotives is illustrated above; although their general layout is basically the same as the earlier class "5" locomotives, certain minor alterations introduced on the later engines with Walschaerts valve gear are incorporated in this design. They have rectangular section coupling rods in place of girder section, hinged front windows on the cab replace fixed ones, and the gangway doors are fixed on the cab instead of the tender. Of the thirty locomotives ten have been allocated to each of the three regions, those for the Western Region being equipped to take automatic train control gear.

Bandsawing Machine

A RECENT addition to the machine tools made by the Startrite Engineering Company, Ltd., Gads Hill, Gillingham, Kent, is the bandsaw illustrated herewith. It has a 20in by 19in work table and its throat depth of 18in and capacity to handle work up to 5¾in thick enables the machine to be used for a relatively wide range of component sizes. Ten blade speeds from 56ft to 3200ft per minute are available and the machine is intended for use with 95in. long bands from ⅛in to ½in wide.

The machine has a rigid one-piece cast frame fitted with a large door giving free access for blade changing. Its cast iron table carries an adjustable fence attachment and is trunnion mounted so that it can be tilted up to 45 deg. to the right and 5 deg. to the left. The saw guide pieces are adjustable through a fine screw control, and the tool guide posts are fitted with ball bearing thrust rollers and steel inserts for lateral blade support.

A welding equipment built into the column of the machine is designed for automatic flash welding of blades from ⅛in to ¾in and includes a weld grinder, a blade squaring shear and annealing means. It is situated in a convenient position for making up bands from coiled stock or rejoining a band after it has been passed through the workpiece. To keep the work clean and assist the operator to follow lines a small air jet is directed on to the work, and there is a low-voltage spotlight fitted above the work station. A job selector dial on the machine shows the operator the type and speed of tool to be used for the class and thickness of the material.

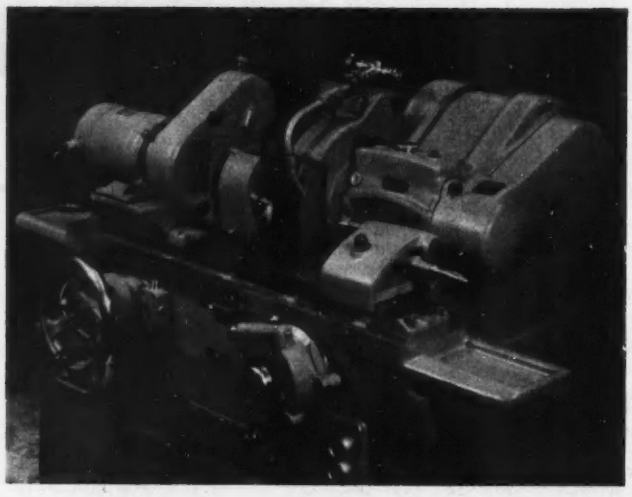


Bandsawing machine with ten speeds from 56ft to 3200ft per minute. It has an 18in deep throat and its 20in by 19in table can be tilted 45 deg. to the right and 5 deg. to the left

Cylindrical Grinding Machine

A CYLINDRICAL grinding machine for work up to 3in diameter by 12in long has been introduced by Myford Engineering Company, Ltd., Beeston, Notts, for either production shop or toolroom use. It is arranged for manual operation and the carriage handwheel is fitted with epicyclic gearing giving two traverse rates of 1·7in and 0·575in of travel per revolution. Both the carriage and the wheelhead move on vee and flat ways and oiling rollers are fitted for lubricating.

The grinding wheel spindle is driven through a flat belt at 2200 or 2500 r.p.m. by a 1½ h.p. motor. The main dial of the wheel feed mechanism indicates 0·0001in increments of infeed, and a dead stop is provided for repetition work. Provision is made for the initial setting of the handwheel abutment in relation to the dead stop, and for wheel wear compensation. Fine settings can be obtained using a separate graduated control which represents 0·0002in infeed per complete



Manually operated cylindrical grinding machine for work up to 3in diameter and 12in long

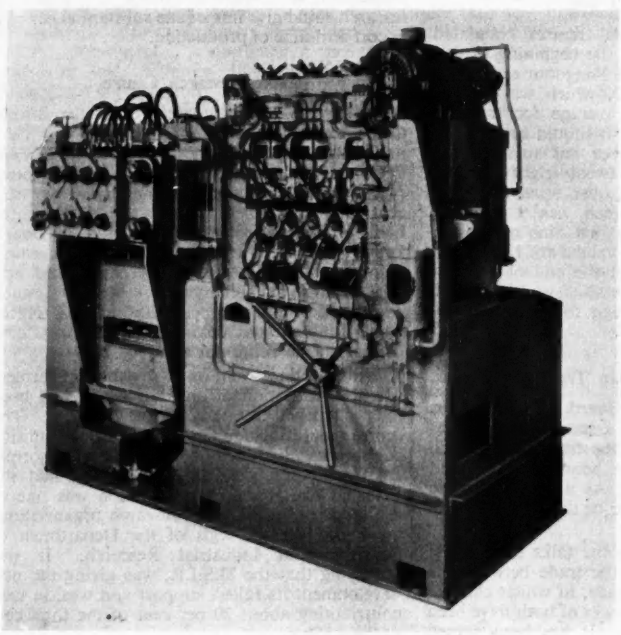
revolution. A stabilising weight is fitted to ensure constant loading of the feedscrew over the whole range of feed.

The worktable of the machine can be swivelled up to 5 deg. each way for taper grinding, and the workhead spindle is driven by a ⅛ h.p. motor giving two ranges of six spindle speeds from 75 to 390 r.p.m. in the low range and 160 to 730 r.p.m. in the high range. It takes collets up to ½in capacity and chucks up to 3¼in capacity. A coolant tank is fitted in the base of the machine and a supplementary tank with a separating system is provided to ensure a supply of clean coolant for fine grinding.

The machine, which is illustrated above, can also be fitted with a removable internal grinding attachment with a capacity from ¼in to 3in diameter. With this attachment, bores up to 3in deep can be ground.

Roller Straightening Machine

A TWO-WAY roller straightening machine for heat-treated steel flats and hexagon bars from 0·44in to 0·75in across the flats has been built by the Bronx Engineering Company, Ltd., Lye, near Stourbridge. The new machine, which is illustrated on this page, has an operating speed of 50ft per minute and handles 80/90 tons tensile material. It is driven by two 10 h.p. motors, one for the horizontal bank of rolls and the other for the vertical bank.



Two-way roller straightening machine for flat or hexagon bars from 0·44in to 0·75in across the flats

Two similar banks of rolls are used, the first bank having eight horizontal rolls and a pair of pinch rolls, and the second bank eight vertical rolls. These rolls are mounted in bronze bearings set at 4½in centres to take 3⅞in diameter rolls 5in long. Necks are formed integrally with the rolls and a claw half-coupling is formed at the driving end. Each of the roll bearing carriers is a single steel casting and can be individually adjusted. One set of carriers in each roll group has a fine setting adjustment for the bar passes and the opposing set is arranged for dual screw adjustment for the primary deflection of the stock.

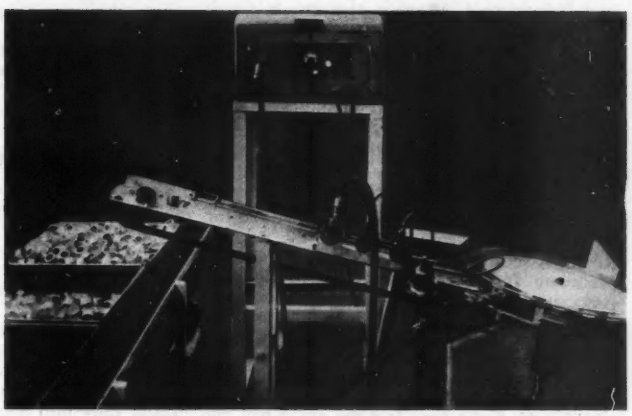
All the rolls are driven through universal couplings from a totally enclosed pinion drive, and the primary drive from each motor to the pinion box consists of a pair of steel gears.

In addition to the above roll adjustments, the complete assembly at the entry side of the machine is adjustable vertically by means of elevating screws and worm gearing, the roll housing being guided in a fabricated steel slide. The roll housing at the delivery side of the machine is adjustable horizontally, the housing being located in slides and traversed by screws and worm gearing. Both roll assemblies can, therefore, be set to suit the position of any passes provided in the rolls, and indicators enable adjustments to be rapidly carried out.

Batch Counting Equipment

IN the illustration below we show a piece of equipment for the counting of metal caps after the final stage of production. The equipment is manufactured by Sutton Coldfield Electrical Engineers, Reddicap Trading Estate, Sutton Coldfield. It comprises a capacity pick-up head with its probe either touching or close to the caps and coupled to a standard batching unit. On completion of the batch a valve is operated which supplies air to actuate two cylinders. One of these traps the flow of caps whilst the other removes and replaces the containers. As this process only takes a fraction of a second, production flow is not interrupted. Counting proceeds at an average speed of 400 per minute with a peak flow exceeding 750 per minute. Accuracy is complete at this speed and tests have shown that considerably higher speeds are possible.

The batching unit can be set to batch in multiples of 100 up to 4900 and includes a "state of batch" indicator which automatically resets and a "number of batches" indicator, which can be hand reset. A capacity pick-up head is used in this instance so that accurate signals can be obtained without separating the caps. Photo-electric, inductive or microphonic units can be coupled to the same batching unit.

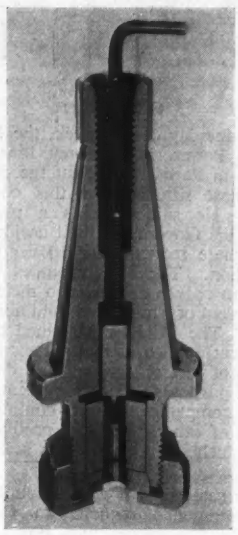


Electronically-controlled, pneumatically-operated batch counting equipment for metal caps

Chuck for Screwed Shank Tools

A CHUCK for use with screwed shank tools and cutters has been developed by the small tools division of B.S.A. Tools, Ltd., Montgomery Street, Sparkbrook, Birmingham, 11, and is now being made in two sizes. The smaller size takes tools of from $\frac{1}{16}$in to ¼in cutting diameter and the larger tools of from $\frac{13}{16}$in to 2in cutting diameter. These chucks are designed to give a high degree of rigidity under heavy cutting conditions, and they are fitted with an adjustable centre, which assists in centralising cutters and provides length adjustment.

The general construction of the chuck can be seen in the accompanying sectional illustration. The body is bored throughout its length, and below the screwed section for the drawbar a reduced section is threaded to take the adjusting screw for the centre, which, when set, is locked by a grub screw. A bush which is a precision fit in the bore at the nose end of the body is threaded at the top of its bore to take screwed cutter shanks of the appropriate size. This cutter bush takes its drive through a substantial key from the body of the chuck. A split taper collet is fitted in the nose below the bush and is held by the locknut in its operative position. When the locknut is tightened the collet takes up variations in cutter shank diameter, and in conjunction with the back centre centralises the cutter in the chuck.



Chuck for screwed shank cutters fitted with adjustable centre for tool centralising and length adjustment

The smaller sized chuck is supplied with four bushes and four split collets for the range of cutters with which it can be used, and the larger chuck with three sizes of complementary bushes and collets.

JET AIRLINER.—British Overseas Airways Corporation is discussing with de Havilland Aircraft Company, Ltd., Hatfield, Herts, the specification of an aircraft for world wide use, including North American crossings, and will place an order for the aircraft when agreement is reached. The project is known as the "D.H.118." The intention is that the new aircraft should have speed and range capabilities comparable with the large American jets, but would be somewhat smaller in size. The carrying capacity envisaged would offer operational flexibility on the majority of the world's air routes which do not have the large traffic potential of the North Atlantic. It would also be capable of operating in and out of existing main line airports without calling for runway reconstruction and lengthening.

Industrial and Labour Notes

Oil Supplies

On Wednesday of last week, the Minister of Fuel and Power, Mr. Aubrey Jones, made a statement in Parliament about the effect of the Middle East situation on this country's oil supplies. He said that as a precautionary measure, the Government had decided to make an immediate reduction of 10 per cent in oil consumption. The oil companies were being required to reduce deliveries to their customers to 90 per cent of what they would normally have supplied. The Minister explained that the 10 per cent cut applied to motor fuels and also to deliveries of fuel oil, gas oil and diesel oil for industrial purposes. For the present, he added, the oil companies would continue normal deliveries of other petroleum products such as aviation fuels, vaporising oil, lubricants and paraffin.

On the same day, it was announced that, at the Government's request, an Oil Industry Emergency Committee had been formed to assist the Ministry of Fuel and Power in dealing with the problems arising from the application of the measures to reduce consumption of petroleum products. This committee consists of representatives of the companies engaged in the distribution of petroleum products in the United Kingdom. The chairman is Mr. C. M. Vignoles.

Some further information about oil supplies was given in Parliament, on Monday, by Mr. Dodds-Parker, Joint Under-Secretary of State for Foreign Affairs. In answer to a question, he said that the three pumping stations on the Iraq Petroleum Company's pipeline in Syria had been destroyed. He also stated that the Saudi Arabian Government had cut off supplies of crude oil to the Bahrein refinery and prohibited the loading of British and French tankers at Saudi ports, and that as a result of the blocking of the Suez Canal by Egypt, all tankers had been diverted round the Cape.

Bituminous Roads Development Group

The various industrial groups responsible for bituminous construction in roads—the Asphalt Roads Association, the Federation of Coated Macadam Industries, and the Road Bitumen Association, have jointly formed a new body which will be responsible for advising and publicising all aspects of bituminous road construction. The new body is known as the Bituminous Roads Development Group and has offices at Cecil Chambers, Strand, London, W.C.2. We understand that the group will not carry out research work, and will exist purely for promoting the best interests of this class of construction; however, there already exist research bodies within the industry, and their results will all be available to the group and will be publicised through it.

Employment and Unemployment

The Ministry of Labour's latest report on the employment situation in Great Britain says that, at the end of September, the total working population was 24,100,000, the same as at the end of August. During September, however, the number of people in civil employment declined by 14,000 to 23,085,000 (15,273,000 men and 7,812,000 women).

An analysis of the civil employment figures reveals that in September the number engaged in the basic industries was 4,014,000, or 8000 fewer than in the preceding month. The decline was seasonal, occurring in transport and agriculture. In the manufacturing industries, the number of people at work in September increased by 23,000 to 9,254,000. This increase was spread over all the manufacturing groups with the exception of vehicle building, in which the number employed fell by 4000 to a total of 1,221,000, compared with 1,246,000 a year earlier. In the "engineering, metal goods and precision instruments" group, there was an increase of 10,000 in the number employed, bringing the total to 2,799,000, which was the same as at the end of September last year. In other industries and services, the principal changes in September were an increase of 6000 in the number employed in building and contracting, making a total at the end of the month of 1,517,000, and a decrease of 29,000 in the number engaged in "professional, financial and miscellaneous services."

About unemployment, the Ministry's report says that on October 15th, there were 254,073 people registered as out of work, compared with 247,640 on September 17th. The October figure represented about 1·2 per cent of the estimated total number of employees; it included 91,000 people who had been out of work for more than eight weeks. The report explains that, in the four weeks ended September 19th, the employment exchanges in Great Britain filled 177,000 vacancies. The number of vacancies notified to the exchanges but unfilled on that date was 334,000, which was 90,000 less than a year previously.

Overseas Trade

According to provisional figures circulated by the Board of Trade at the beginning of this week, the value of United Kingdom exports in October was £294,900,000, which was 14 per cent above the monthly average for the first nine months of this year. It should be borne in mind, however, that October was an unusually long month, there being twenty-eight working days. Imports during October were valued at £354,300,000, a figure which was 9 per cent above the average for the first nine months of the year. Re-exports were valued at £12,700,000. The visible trade deficit at the end of October was, therefore, £46,700,000, which was £6,000,000 below the monthly average for the January-September period.

United Kingdom-Australian Trade Agreement

The President of the Board of Trade, Mr. Peter Thorneycroft, made a statement in Parliament on Monday about the trade talks which have recently taken place between the United Kingdom and Australia. As a result of these talks a new agreement is to be drawn up early in the New Year.

A joint communique on the talks says that a comprehensive review of the trade between the two countries has been made, in which changes in the economic circumstances of both have been taken fully into account. It has been agreed that the time is now opportune for changes in the contractual arrangements between the United Kingdom and Australia. To that end, the United Kingdom will maintain tariff preferences and duty-free entry enjoyed by Australian goods, and Australia will maintain tariff preferences for United Kingdom goods subject to reductions in the level of guaranteed margins. During the talks, the communique adds, specific arrangements were made for close consultation between the two governments about "a wide range of trade and related matters, including anti-dumping and countervailing duties, agricultural policies, transport and communications, and disposal of surpluses."

The intention is that the new agreement shall operate initially for five years. Arrangements will be made for the two governments to review the operation and future application of the agreement as a whole some months before the end of that period.

Production Research in America

In an address to the Production Engineering Research Association recently, Dr. D. F. Galloway dealt with some of his impressions as a result of a two months' tour in the United States and Canada. During this tour, he said, he had been greatly impressed by the volume of production engineering research in the United States and by the enthusiasm with which the results of this research were applied in industry. During 1955 the total estimated expenditure on research and development in the United States was £2000 million as compared with about £250 million in this country. The number of research workers in America, Dr. Galloway continued, was about 500,000, whilst in this country it was about 60,000. Even when the difference in populations was taken into account our research effort was small when compared with that of the United States, and this was probably one of the main reasons why our annual increase in productivity was about 1·5 per cent, or half that in America.

Speaking about automation, Dr. Galloway said some examples in Britain compared well with those in the United States, but in that country there was generally a better climate for the growth of new ideas. He stressed that higher productivity was being achieved to-day not only by automation, but by raising the efficiency of basic production techniques for some of the really wasteful methods that were at present widely used. The application of improved production techniques developed as a result of research could give immediate substantial savings in cost and time of production.

Coke Research Centre

During the annual conference of the British Coke Research Association, which was held in London last week, the chairman, Mr. Leslie O'Connor, stated that orders had now been placed for the erection of a new coke research centre at Chesterfield. The site for the centre had been leased from the National Coal Board and was adjacent to the Avenue carbonisation plant (see THE ENGINEER, November 2nd and 9th). The research centre, Mr. O'Connor explained, would comprise laboratories, offices and a full-scale test coking plant, the total cost of the scheme being put at £500,000.

Mr. O'Connor went on to say that this project was the realisation of an ideal which had been long cherished by the coking industry. The centre would include equipment for carbonising coal on a scale directly comparable with normal coke oven practice. He pointed out that the British Coke Research Association was one of the industrial grant-aided research organisations coming under the ægis of the Department of Scientific and Industrial Research. It was gratifying that the D.S.I.R. was giving the new development its fullest support and was, in fact, contributing about 20 per cent of the total cost of the scheme.

Management Education

The British Institute of Management has just published a book entitled *Education and Training in the Field of Management*. This volume gives a complete survey of the facilities for management education in Great Britain. It sets out details of the courses in management and allied subjects which are at present operating at thirty universities and associated colleges of technology, 252 technical colleges and nine adult education centres. There are also particulars of courses which are administered by fifty-five professional and specialist organisations.

The book shows that there is a total of 188 courses, specifically devoted to general management, which are now available in this country. Of these, nineteen are operated by universities and colleges of technology, 128 by technical colleges, fifteen by adult education centres, and twenty-six by professional and specialist bodies. Dealing with more specialised courses, the volume lists 108 which are concerned with production management, twenty-eight on personnel management, forty-three on human relations and communication, thirty-two on finance and statistics, and eighteen on office management. There are also particulars of fifteen courses for trade unionists.

The price of the book is 21s. It may be obtained from the British Institute of Management, 8, Hill Street, London, W.1.

Aluminium Road Bridge at Lünen

On July 26, 1956, the first German aluminium road bridge was placed in position. This bridge (the Schwansbell Bridge, over the Datteln-Hamm Canal, near Lünen, Westphalia) has a span of 44·20m, a clear width of 4·50m, and a weight of 25 metric tons. It is suitable for lorries up to 12 tons (Class 12 of German standard DIN 1072). The bridge was built by Dortmunder Union Brückenbau A.G.

THE Schwansbell Bridge, No. 464, over the Datteln–Hamm Canal, near Lünen, was placed on its abutments on July 26th this year. It is constructed of aluminium alloy and—in contrast with the aluminium footbridge erected in Düsseldorf in 1953, which is a plate girder bridge—is a lattice girder design. It carries local road traffic over the canal and is the first aluminium road bridge to be built in Germany.

The fact that in Germany aluminium alloy is a comparatively new and untried material for this class of work determined many aspects of the design. While it might have been preferable to employ more extensively ideas developed in connection with airframe construction, such as "shell" design, anisotropic decking and tubular sections, this course had to be avoided for two reasons. The nature of the order, especially the financial aspect, precluded any major experiment; moreover, it was desired to test as many different aspects of aluminium construction as possible. Consequently, a kind of design was chosen which allowed the structure to be built from a large variety of components. As may be seen from our illustrations, the bridge was built similarly to a steel bridge, but extensive use was made of extruded sections.

The material used was the alloy Al Mg Si F32, which, in accordance with the German standard DIN 1725, has the following composition:—0·6 to 1·4 per cent magnesium, 0·6 to 1·2 per cent silicon, 0·6 to 1·0 per cent manganese, 0 to 0·3 per cent chromium, and the remainder aluminium. The alloy has an ultimate strength of 3200 kg per square centimetre, a yield point of 2500 kg per square centimetre, and an ultimate elongation of 8 per cent. Permissible working loads, according to DIN 1073, were, for main and subsidiary loads: in tension, 1460 kg and 1670 kg per square centimetre; the same values for bending, both cases with a factor of safety of 1·71 for main and 1·5 for subsidiary loads. In shear, the working stresses were 880 kg and 1000 kg per square centimetre with the same factor of safety. For cohesion the transition from plastic to elastic failure (Johnson parabola/Euler hyperbola) was at a slenderness ratio of 74·3. A safety factor of 1·71 to 2·5 was used in the plastic range and 2 to 5 in the elastic range. Rivets were of age-hardened Al Mg Si alloy according to DIN 1748, and working stresses of 700 kg and 800 kg per square centimetre were used for main and subsidiary loads, giving a factor of safety of about 2.

One advantage of light alloy construction is that use can be made of extruded profiles of almost any degree of complexity. Limitations are imposed, however, by the high cost of the tooling required, if this cost cannot be distributed over a large output. In the present case, the quantities were small and therefore profiles had to be chosen for which there would continue to be a market.

The capacity of the biggest available bar extrusion presses, which had a toolholder diameter of up to 400mm, also limited the choice of sections to those which could be inscribed in a 350mm diameter circle.

Existing stretching presses, used for straightening the extruded material, can deal with cross sections of up to 90 square centimetres.

It will be seen from Fig. 1 that because of limitations of the size of cross section which could be extruded and afterward subjected to the necessary straightening, the top booms had to be built up from two components, instead of a single section being used. The alternative would have been to extrude a section with a curved centre plate which could have been flattened out subsequently. While this would have been technically feasible it would have added to the cost. The fact that the booms are constructed of two Z-sections joined by riveting has the advantage that variations in width of the struts and ties can easily be accommodated by leaving the reaming of the boom rivet holes at the nodes, and the riveting itself, until these members have been put into position.

Another possibility for the booms would have been a rectangular box section either extruded in one piece or formed from two channels riveted or welded together. This was not chosen because of the problems of stiffening the walls of the box against buckling, and the need when using channels of having two longitudinal joints.

The bottom boom is built up from two channels back-to-back and enclosing the vertical and horizontal cross members. Between joints are placed a number of spacers. The smaller top flanges of the bottom boom channels are required to prevent deformation during manufacture and assembly.

The end diagonals are of the same section as the top boom, the others are I or □-sections, depending on whether they are ties or struts. Because of the small metal thickness of the I-sections, the edges are reinforced by bulbs. Top and bottom wind bracing is provided, the top wind forces being transmitted downwards through the portal frames at each end.

It was considered to be of particular importance to use a light alloy deck construction, rather than reinforced concrete. Experience in this respect was desirable because it would seem possible on many existing bridges to replace the existing decking by aluminium; this would raise the load capacity, since up to 50 per cent deadweight can be saved.

The decking is formed of special "double T" sections with curved top flanges (see Fig. 1). The increased stiffness of the curved flanges is intended to prevent deflection which could cause cracks in the asphalt layer 6cm thick which is placed on top and which forms the road surface. The whole of the road deck is carried on three longitudinal beams spaced at the bridge centre line and 1·75m on either side. Compared with a 16cm thick reinforced concrete deck, weighing 384 kg per square centimetre, and a 5cm asphalt layer (110 kg per square metre)—together 494 kg per square metre—the aluminium decking and 6cm asphalt layer weigh 56 kg and 123 kg per square metre, respectively, making a total of 179 kg per square metre, which is substantially

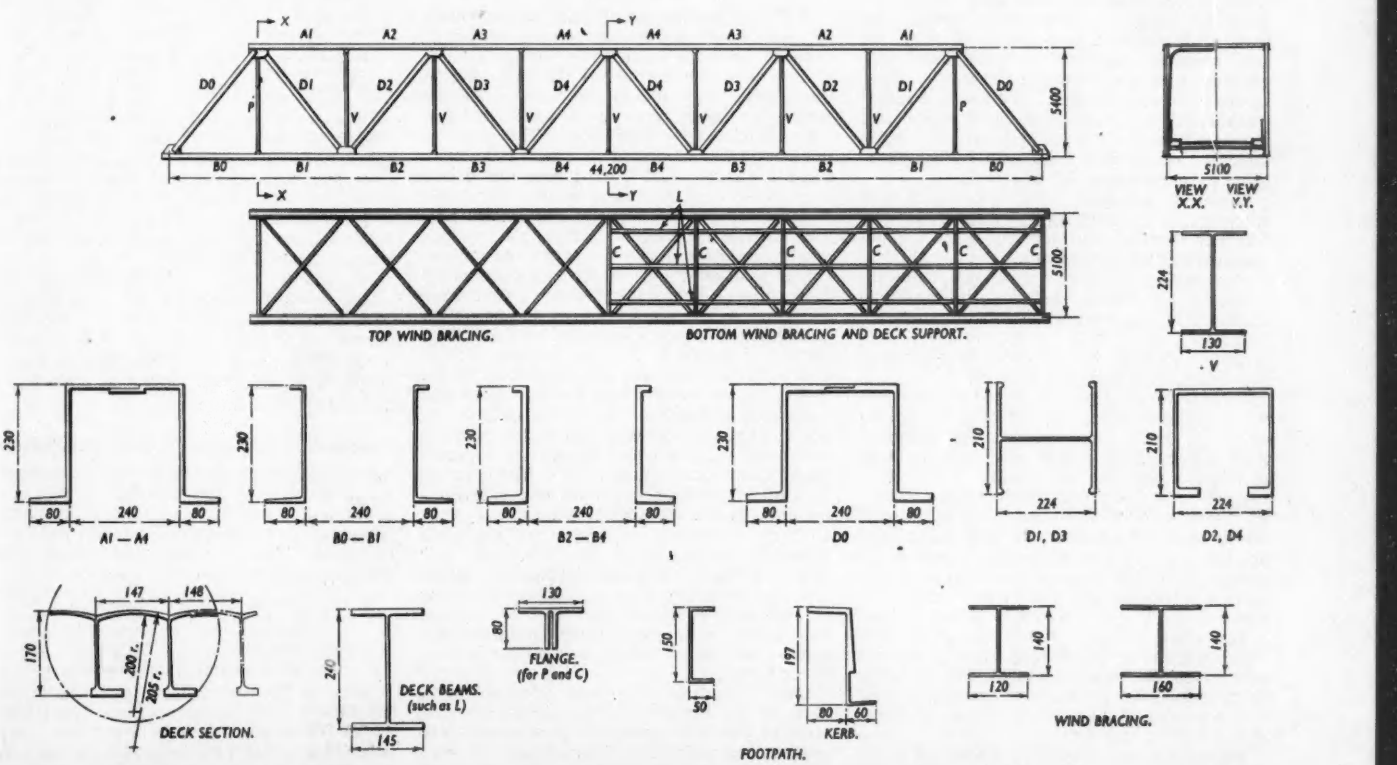


Fig. 1—Schwansbell road bridge. Details of the various extruded aluminium alloy sections of the bridge members are shown. All dimensions are in millimetres

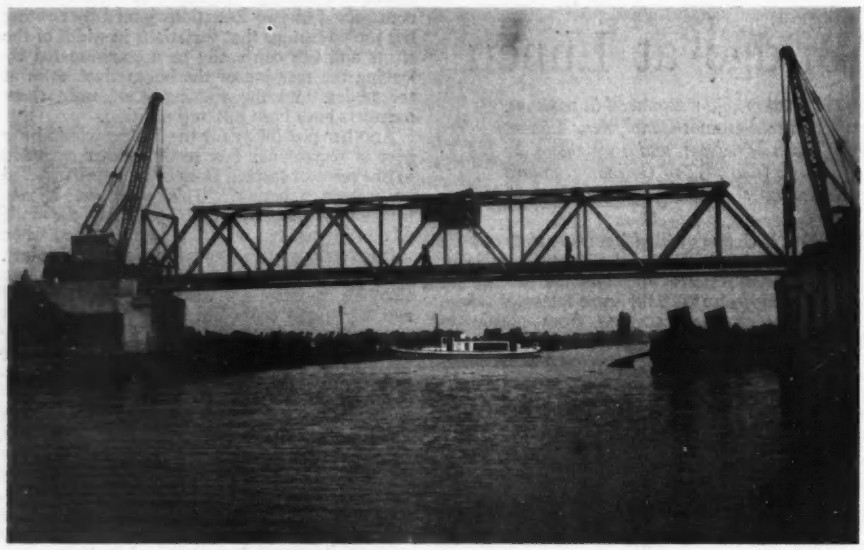


Fig. 2—Schwansbell bridge being placed on its sockets. It was transported to the site fully assembled by means of the two pontoons shown. With a span of 44·20m and a useful width of 4·50m, this aluminium structure weighs 25 tons. It is designed for lorries up to 12 tons

less. The lighter decking also makes possible a saving of about 1·6 tons of metal in the main girders. The footpaths are constructed of rolled sheet with a dimpled non-skid surface.

Thermal expansion is twice that of a steel design, and for the specification range of ±35 deg Cent. the total change in length is 102mm. Lintels had therefore to be used ; these were made of " St 37 " steel in order to avoid excessive wear. To prevent corrosion, the steel was hot-dip galvanised and separated from the aluminium by an insulating layer. The bridge railings are made of extruded aluminium profiles which were anodised. The same shapes, but of steel, are used on the adits.

Construction

In order to avoid contamination, especially of the joints, with iron swarf or filings, the fabrication was carried out in a separate bay of the works, equipped with radial drill, metal shears, circular saw and band saw. Both saws were of standard woodworking design for hand feed, equipped with special blading. All steel assembly jigs were carefully lined with wood in order to avoid damage, especially stress-raising nicks and scratches. For the same reason marking-off was done with hard pencil and instruments made of plastic material. The shears table and clamp were lined with rubber sheet, as were the press bending tools used.

Standard high-speed drills as for steel were employed, holes being drilled 2mm under size for later reaming, and deburred with a hand-operated 120 deg. countersink.

For bending the bridge deck sections at the centre by the required 1·5 deg., it was found necessary to clamp up the webs with hardwood liners to prevent buckling in the press. All grooves and blemishes were carefully removed everywhere by grinding or scraping.

Because of the lightness of the components, which could be lifted by one or two men, no cranes or hoists were required for assembly. Zinc or cadmium-plated steel screws with aluminium washers were used. Holes were reamed to at most 0·2mm over size. Rivets of 10mm, 12mm and 16mm diameter were set in the cold by means of pneumatic tools specially adapted to avoid cuts and dents of the work. Many experiments had previously been carried out to find the best shape of rivet head for setting. This was found to be a pan head rather than a round head, the proportions depending on the rivet diameter. All joints were painted on the contact surfaces with a coating of " Lindolin F 64." It is not intended to paint the remainder of the structure, unless experience shows it to be necessary.

The bridge was completely assembled at the " Orange " branch works of Dortmunder Union Brückenbau A.G., at Gelsenkirchen, and was transported to the site by waterway. At each end one large cylindrical float was linked on, so that the bridge could be towed in a partly submerged position in order to clear various bridges. Several locks had also to be passed *en route*,. On arrival, the floats were detached from the ends and placed underneath the bridge, one end being dealt with at a time. This raised the bridge above the level of the banks, enabling it to be turned at right angles to the canal and floated against the piers. It was then raised on the abutments by means of two mobile cranes. Finally, the asphalt surface was placed on the deck.

The design and construction were carried out by Dortmunder Union Brückenbau Aktiengesellschaft, Dortmund, Sunderweg 86, German Federal Republic.

Fifty Years of German Long-Distance Radio

Half a century has passed since representatives of twenty-seven nations assembled in Berlin, in October, 1906, for the first international conference on radio communications. On that occasion the delegates were able to visit the experimental station at Nauen, near Berlin, which had just been completed by Telefunken. The aerial of this station was supported on a mast 100m high. Current was obtained from a generator driven by a 35 h.p. portable steam engine. The transmitter comprised a battery of 360 Leyden jars, each nearly a metre high, which supplied a spark gap giving about twenty discharges per minute. On the occasion of the visit the station succeeded in reaching St. Petersburg, bridging a distance of 1300km. A few years later, by means of the quenched spark system developed by Telefunken, the record set up by Marconi between Ireland and Newfoundland was almost doubled, when New York was reached from Berlin, representing a distance of 5200km. Before the outbreak of war in 1914, the long-wave transmitters designed by Count Arco had made Nauen the centre of the first transoceanic radio system. This concern, built up by Telefunken without state aid, transmitted to North and South America, and to the German possessions in Africa and the East. While the outcome of the first world war destroyed the German colonial network, it did not affect Nauen for long. Already in the spring of 1918, regular transmissions to New Zealand had begun. Soon after the end of hostilities it proved possible to resume commercial services to the U.S.A.

Other long-distance stations were built in all parts of the world. In 1923, Telefunken constructed the first commercial shortwave transmitter, which took up the transmission to Buenos Ayres. This inaugurated the era of directional aerials, which permitted wireless telephony between continents by concentrating the radiated energy in the required direction. By 1931, the operating company " Transradio " had already in use sixteen directional stations in addition to its long-wave transmitters achieving an annual transmission of 18,000,000 words.

On January 1, 1932, Nauen station was taken over by the German postal authorities. In 1946, the transmitting equipment was dismantled by the Russians, and the aerial masts blown up. Since then, new and improved receiving and transmitting stations have been commissioned by the Deutsche Bundespost near Frankfurt.

Swiss Foreign Trade

Compared with the first nine months of last year, imports into Switzerland during the first three quarters of 1956 have increased by 805·3 million francs, or 17·3 per cent, to a total value of 5450·7 million. Substantial increases have also taken place during the same period in the amount of exports, the increase being 392·2 million francs, or 9·8 per cent, to a total of 4413·4 million francs. On September 30th, the adverse trade balance therefore amounted to 1037·3 million francs, as compared with 624·2 million francs a year before. Most of the increase in exports has been due to products of the engineering industry. This is illustrated in the following tables :—

Total Swiss Foreign Trade and Main Categories

(Millions of francs)

First 9 months	Total	Food-stuffs	Raw materials	Manu-factures
Imports :				
1949	2807·6	854·7	971·8	981·1
1955	4645·4	961·6	1611·6	2072·2
1956	5450·7	1090·8	1936·9	2423·0
Exports :				
1949	2495·5	109·3	81·4	2304·8
1955	4021·2	185·4	176·3	3659·5
1956	4413·4	224·7	178·2	4010·5

Principal Swiss Exports

	January–September (millions of francs)		Price index in third quarter (1949 = 100)	
	1955	1956	1955	1956
Textile industry	564·2	604·6	96	99
Metals industry	2131·2	2364·3	99	99
Comprising :				
Aluminium	54·2	55·0	114	124
Machinery	881·9	970·1	88	87
Watches	735·5	829·2	106	107
Instruments	292·5	317·1	96	84
Chemical industry	687·6	726·6	72	69
Comprising :				
Pharmaceutical	301·2	326·6	68	66
Heavy chemicals	111·2	127·0	67	62
Aniline dyes	205·4	201·8	73	72
Foodstuffs and tobacco	226·0	261·3	91	90

Most of the exports during the first three quarters of 1956 went to West Germany (14·1 per cent), then come the United States of America (11·8 per cent), France (8·9 per cent), Italy (8·1 per cent), Great Britain (5·4 per cent), Belgium-Luxembourg (4·6 per cent), and the Netherlands (4·1 per cent).

As regards imports into Switzerland, West Germany again heads the list with 24·4 per cent, then follow the U.S.A. (12·9 per cent), France (11·1 per cent), Italy (9·6 per cent), Great Britain (5·4 per cent), Belgium-Luxembourg (5·0 per cent), and the Netherlands (4·6 per cent).

Growth of Urban Populations in Germany

According to the Rationalisierungs-Kuratorium der Deutschen Wirtschaft (RKW), the urban population of the German Federal Republic is continuing to increase while the rural population decreases. The percentage distribution of increases is as follows :—

	Per cent
Communities with 2–5000 inhabitants	3·2
Communities with 5–10,000 inhabitants	6·8
Communities with 10–20,000 inhabitants	9·4
Communities with 20–50,000 inhabitants	12·1
Communities with 50–100,000 inhabitants	12·6
Communities with over 100,000 inhabitants	15·7

Since 1950, communities with under 2000 inhabitants have decreased from 13,800,000 to 12,700,000 people, a loss of 8 per cent. On the other hand, the fifty large towns with over 100,000 inhabitants have shown an increase from 13,300,000 to 15,300,000.

Calibration of High-Pressure Test Standards

BY OUR AMERICAN EDITOR

To keep pace with the increasing use of high pressures in industry and scientific research, the National Bureau of Standards, Washington, D.C., has undertaken the development of instruments and standards that will permit a more accurate measurement of pressures up to about 200,000 lb per square inch. The article reviews this work and describes a special deadweight piston gauge which was recently developed at the N.B.S. as a primary standard of pressure. It also outlines an arrangement for pressure measurement at phase transition fixed points with the aid of resistance wire gauges.

UP to the present, nearly all measurements in the field of high pressures up to about 200,000 lb per square inch have been referred to fixed-pressure points, associated with phase transitions in water and mercury. Yet the need for accurate high-pressure measurements continues to grow as higher and higher pressures come into use, and additional determinations of fixed points are needed. A complete list of the applications of high pressure and its measurement would cover a range of processes from the production of artificial diamonds to the manufacture of ordnance ; it would include the extrusion of metals and plastics, the operation of oil wells, and a wide variety of operations in chemical technology. Geophysicists have been making pressure measurements in this range for many years. A recent application is the study of the high pressures generated by nuclear explosions.

Pressures of 150,000 lb per square inch and above are used in the field of ordnance, both in laboratory studies and in such large-scale operations as the pressure seasoning of cannon bores. Perhaps the best illustrations of the higher pressures now being extensively used are provided by chemical technology, especially in connection with catalytic polymerisation and hydrogenation. The commercial production of such substances as polyethylene makes use of pressures in the range of 15,000 lb to 50,000 lb per square inch, and industrial laboratory studies of new polymeric substances are moving into the range from 100,000 lb to 200,000 lb per square inch. In the hydrogenation of coal, pressures as high as 100,000 lb per square inch are currently being used to produce a variety of chemical products such as benzene, toluene, aniline, cresols and

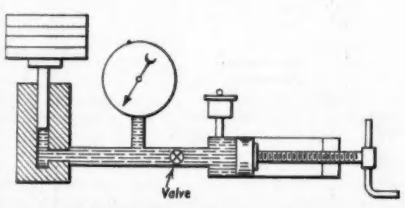


Fig. 1—Simple deadweight piston gauge for measuring low pressures

indole. Experience has shown that pressure-measuring or controlling instruments should be calibrated with an accuracy better by a factor of about three than the accuracy within which the instrument is intended to work. This places severe requirements on the accuracy needed in the fundamental pressure standards in order that industry may manufacture and maintain devices for process control at an accuracy within 1 per cent. The process control instrumentation should then have greater than 0·3 per cent accuracy, the bench standards for calibrating these should have been accurate within 0·1 per cent, and the master standard greater than 0·03 per cent. The National Bureau of Standards, serving as the monitor of the master standards in the United States, should then have fundamental standards within 0·01 per cent accuracy. The work of research laboratories, often requiring data accurate to 0·03 per cent, makes even more stringent demands, requiring primary standards of accuracy greater than 0·01 per cent. Actually, these estimates are minimal, and accuracies considerably higher than the 0·01 per cent now attainable with the Bureau's piston gauges would be very desirable.

At present, the Bureau's programme on high-pressure standards and measuring techniques is proceeding along several different, but related, lines of approach. One principal effort is in the development of piston gauges for the absolute measurement of pressure up to 200,000 lb per square inch. Other objectives of the programme are : (1) the determination of a series of fixed points on the pressure scale ; (2) the establishment of standards for the calibration of dynamic pressure-measuring instruments ; (3) the investigation of the properties of working pressure gauges, such as those which utilise changes in electrical resistance with pressure, and (4) the design and construction of mercury columns to serve as primary standards and for measuring differential pressures of several atmospheres at total pressures up to 30,000 lb per square inch.

Primary Standards

A primary standard of a physical quantity is not calibrated in terms of another instrument measuring the same quantity, but can be referred directly to basic standards of mass, length and time. Furthermore, the device used in the measurement should be so simple that errors inherent in the instrument can be either eliminated or accurately evaluated. Two commonly used primary standards of pressure are the mercury column and the deadweight piston gauge. At low pressure the mercury column may be the more accurate of the two, but its range is limited by considerations of convenience. A pressure of 20 lb per square inch corresponds approximately to a convenient 40in of mercury ; but 30,000 lb per square inch would require a mercury column about a mile high. The Bureau's programme calls for the construction of a mercury column 8m high, capable of extension to 20m if desired.

The principle of the deadweight piston gauge is most easily seen in the simple instrument illustrated in Fig. 1, which is in common use for measurements up to a few thousand pounds per square inch. The metal piston fits closely into the cylindrical opening and is in contact below with a confined fluid. Weights may be placed on top of the piston or be suspended below it by a yoke. A hand pump is used to increase the pressure until it is sufficient to raise the piston and weights free of the lower stop. If friction can be neglected, the pressure is equal to the weight of the piston and its load divided by the cross-sectional area of the piston. To reduce friction between the piston and cylinder, the piston is rotated or oscillated, the weights may move with the piston, or the latter may move independently. At high pressures, it is particularly important that leakage of fluid past the piston be kept small to ensure sufficient floating time to establish equilibrium and to make the required observations.

Figs. 2, 3, 4, and 5 illustrate the piston gauge which is now in use at the Bureau. This gauge has the interesting property that the clearance between piston and cylinder can be controlled by an independent pressure applied externally to the cylinder. The control of this clearance makes it possible to calculate the pressure under the piston with greatly improved accuracy. The design also permits the insertion of different piston-cylinder combinations so that the pressure range can be varied from 0–5000 lb per square inch to 0–200,000 lb per square inch. As shown in Fig. 2, the piston *A* is contained in a jacketed cylinder *B*. An independent pressure between *B* and the jacketing cylinder *C* controls the clearance between the piston and the jacketed cylinder. The jacketing cylinder is sealed off by Bridgman

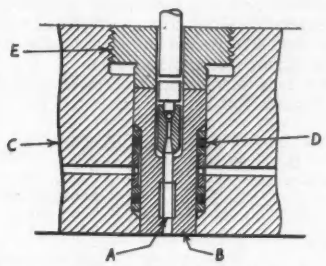


Fig. 2—Cross section of head of N.B.S. deadweight piston gauge serving as primary standard of high pressure

unsupported area rings *D*, whose initial seal is made by mechanical load from the nut *E*. The thrust bearing at the top and a steel ball deliver the deadweight load to the piston which rotates independently of load ; the thrust bearing floats on high-pressure lubricating oil at 10,000 lb per square inch. Fig. 3 shows an exploded view of the piston and cylinder assembly. A deadweight load, which is not shown, is transmitted through the ball-in-cup thrust bearing to the guide bearing with projecting torque arms and to the piston. The piston fits into the cylinder, which is shown partially inserted into its sleeve, and comes in contact with the pressure fluid. The piston and guide bearing are rotated independently of the deadweight load, reducing the friction between piston and cylinder. However, friction now appears at the thrust bearing, and this is reduced by floating the thrust bearing and its deadweight load on a cushion of lubricating

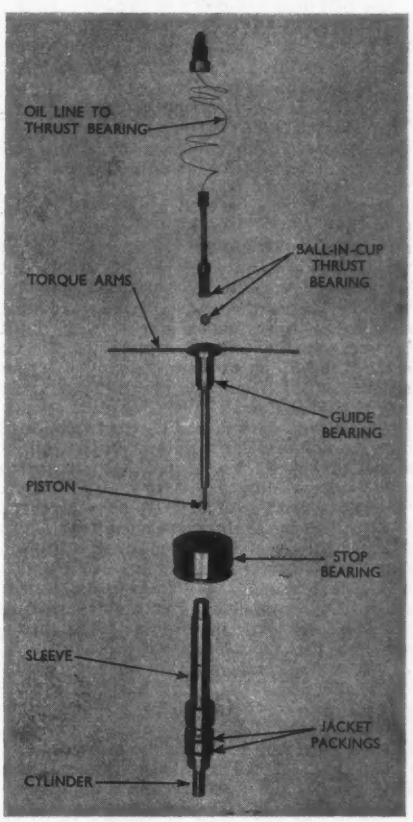


Fig. 3—Exploded view of piston and cylinder assembly of N.B.S. deadweight piston gauge

oil at 10,000 lb per square inch. The oil is brought in through the fine-bore tube and passes down through the centre of the thrust bearing. Fig. 4 is an outline drawing of the N.B.S. controlled clearance piston gauge. The jacketing cylinder, containing the thrust bearing, piston and cylinder, is just below the pulley. The loading system consists of nine 100 lb steel "platters" held in chain suspension attached to the yoke. The platters are lifted on and off the suspension by a hydraulic jack. The yoke suspension rods are electrically insulated from the upper cross rail so that electrical tests can show that the weights are supported by the piston and are free of other parts.

Two such instruments are currently in use at the Bureau for measurements in the ranges

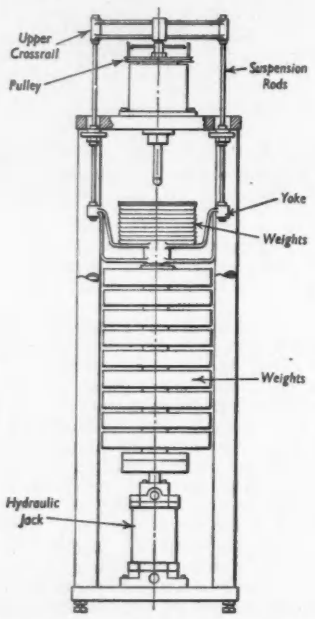


Fig. 4—N.B.S. controlled-clearance piston gauge

0–20,000 lb per square inch and 0–60,000 lb per square inch respectively. The deadweights, which are made of non-magnetic stainless steel, are held in a chain suspension attached to a yoke. There are nine 100 lb "platters" that may be lifted on or off the suspension by a hydraulic jack at the base, and smaller 5 lb and 10 lb weights for hand loading.

Since 1952, when they were first constructed, these controlled clearance piston gauges have undergone a succession of refinements. The first problem requiring attention was quick to appear. The design is such that the weights do not rotate with the piston, the vertical weight load being delivered to the rotating piston by a thrust bearing. In the original bearing the friction made necessary an excessive amount of torque to turn the piston under deadweight loads above 300 lb. The Bureau then designed another thrust bearing which floated the deadweight load on a cushion of high-pressure lubricating oil, as shown in Fig. 4. This reduced the torque to only a few inch-ounces even for loads of 1000 lb. Oil under a pressure of 10,000 lb per square inch is carried to the bearing through a tube of the kind used for hypodermic needles with 0·008in bore. It was soon apparent that improvement was needed also in the roundness and surface finish of the cylinders. Precise measurements on the cylinders were made with a special instrument at the U.S. Naval Gun Factory. A 20,000 lb per square inch cylinder was finally operated successfully with a tungsten carbide piston. Fall rates of 0·02in per hour were obtained, which is about 100 times slower than that obtained with commercial piston gauges.

Tests in the 60,000 lb to 120,000 lb per square inch range showed the need for an extreme degree of coaxial alignment between piston, cylinder and certain other parts of the rotating system, and an appropriate design modification was developed. Also, new cylinders were obtained having the necessary roundness and surface finish. However, it was found that the abrasive material remaining in their bores as a result of the high-speed grinding used in their fabrication resulted in rapid wearing of the piston in use. Two experiments were started at this point. The first was to have the N.B.S. machine shop division make a 60,000 lb per square inch cylinder from raw material without resorting to high-speed grinding. It proved possible to make a cylinder which was free from residual abrasive material and whose most critical profile fell completely between two circles differing by only 7 micro-inches in radius. A tungsten carbide piston was fabricated to fit, and the combination has performed satisfactorily in initial trials. The second experiment was to hone out the 0·079in, 200,000 lb per square inch cylinder to about 0·081in to remove residual abrasive and to have a piston fabricated to fit.

Fixed Points

The determination of the sharply defined pressures at which phase transitions occur in various substances serves at least two important purposes. On the one hand, it makes possible a check on long-term changes in the primary standards. On the other hand, it answers the problem created by the non-portability of primary high-pressure standards, since the measurement of an appropriate number of fixed points can be used for the calibration of working standards.

Some useful high-pressure fixed points are the melting pressure of mercury at 0 deg. Cent., about 110,000 lb per square inch, the melting pressure of water at 30 deg. Cent., about 150,000 lb per square inch, and the transition between the crystalline states of bismuth, near 350,000 lb per square inch. The boiling pressure of carbon dioxide at 0 deg. Cent., about 500 lb per square inch, has certain advantages over atmospheric pressure as a reference point for high-pressure measurements. It is possible that the carbon dioxide point will be the first pressure point used for international comparisons. The use of these fixed points requires that the temperature of the material be measured to within 0·003 deg. Cent., to obtain a pressure accuracy of 0·01 per cent. The pressures are much less dependent on the temperature in certain of the ice-ice transitions than for the melting and boiling pressures. Thus, a measurement of temperature to within 0·05 deg. Cent. will fix the pressure on the ice I-ice III transition near 30,000 lb per square inch to about 0·01 per cent.

Triple points, which are unique in both temperature and pressure, seem to have advantages over transitions in which pressure depends on temperature. A particularly valuable set of triple points is that associated with water at about 30,000 lb, 50,000 lb and 90,000 lb per square inch. These would give, in a single experimental set-up, a three-point calibration covering a range of considerable industrial interest. Largely to test the possibilities of the controlled clearance piston gauge, and to acquire experience with this experiment, a determination of the melting pressure of mercury at 0 deg. Cent. was made at the Bureau. Melting pressure readings were first taken with a gold-chromium wire pressure cell which was afterwards calibrated with the piston gauge, as shown in Figs. 6 and 7. The value obtained agreed with Bridgman's result, published in 1912, to within 0·5 per cent. Fig. 6 is a diagram of the experimental arrangement for measuring the melting pressure of mercury at 0 deg. Cent., or about 110,000 lb per square inch. The pressure is measured with a gold-chromium resistance wire gauge. Afterwards the gold-chromium gauge is calibrated against the controlled-clearance piston gauge. Freshly distilled mercury is sealed in a polyethylene sack in an ice bath. The three lines above the gold-chromium gauge lead to an a.c. resistance bridge. The use of two laboratory intensifiers and three hand pumps are indicated. The displacement fluid, connected to a sight glass, measures the displacement of the intensifier (*A*). The system was first charged to about 10,000 lb per square inch by the hand pump shown at the extreme left. The piston of intensifier (*B*) was then advanced to the end of its stroke, raising the pressure to about 90,000 lb per square inch. The pressure is retained in the system between operations by means of the valves. From then on, the pressure is raised a little at a time by advancing the piston of (*A*) until the mercury begins to solidify. As the mercury solidifies, it shrinks, so that the apparent volume of the high-pressure fluid decreases while the pressure remains constant at the melting pressure. The changes in volume are followed with the sight glass while simultaneous readings are taken on the gold-chromium pressure gauge.

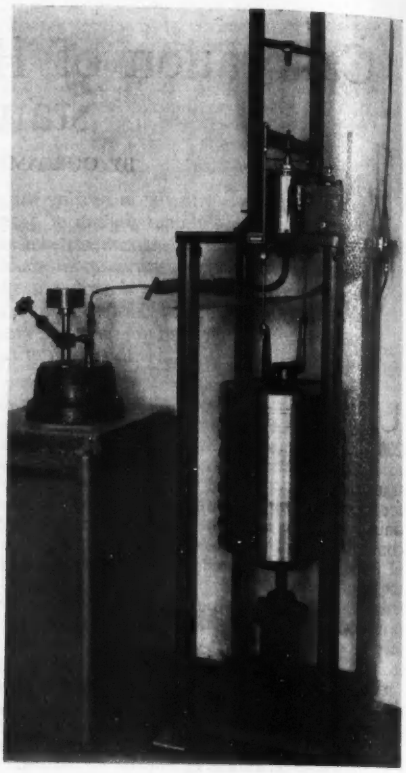


Fig. 5—N.B.S. controlled-clearance piston gauge primary standard used to calibrate instrument at left

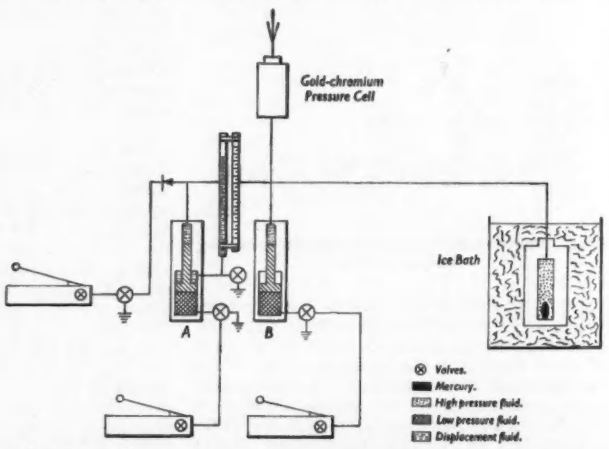


Fig. 6—Experimental arrangement for measuring the melting pressure of mercury at 0 deg. Cent.

Fig. 7 is a diagram of the experimental

arrangement for calibrating a gold-chromium gauge against the N.B.S. controlled-clearance piston gauge or deadweight tester, performed as part of the determination of the melting pressure of mercury at 0 deg. Cent. The manganin resistance wire gauge was used for determining the constancy of the independent pressure used for adjusting the clearance between the piston and cylinder within (*B*). The pressure generated by the hand pump (*A*) is balanced by deadweights. The pressure is calculated from the size of the piston and the deadweights. The readings of the gold-chromium cell are then compared with the calculated values of the pressure.

Exploratory experiments have also been conducted in the region of the ice I-ice III liquid triple point near 30,000 lb per square inch and experimentation has been performed with ice-VI and liquid in two-phase thermal equilibrium at about 140,000 lb per square inch. It is now planned to investigate the other fixed pressure points below 60,000 lb per square inch.

In order to carry out these investigations, accessories capable of generating and containing without leakage pressures up to 200,000 lb per square inch and ultimately up to 350,000 lb per square inch are needed. Some commercial components suitable for pressures of the order of 200,000 lb per square inch are available. However, the requirement of complete freedom from leakage in the present work has necessitated the modification of a large proportion of the commercially obtained equipment. To illustrate this point, an experiment on the phase transition between water and ice-VI may become meaningless if a leak exists of one or two drops per week at 150,000 lb per square inch. Such a leak occurred in an early trial and was traced to the moving seal of the intensifier in use. Other intensifiers were checked and showed

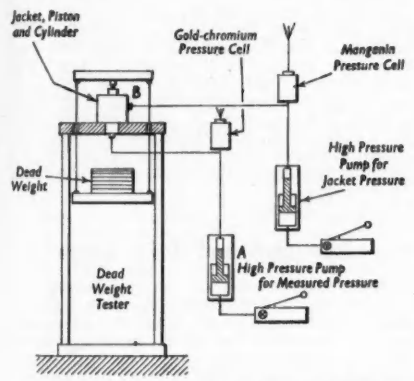


Fig. 7—Experimental arrangement for calibrating a gold-chromium gauge against the N.B.S. deadweight tester

comparable leakage. After much experimentation, the packing configuration was redesigned and the packing material changed so that leakage was no longer detectable. At the same time, ease of assembly and dismantling was improved and packing friction was reduced.

Resistance Wire Gauges

One of the most convenient and universally used methods of measuring high pressures depends on the fact that the electrical conductivity of most substances changes as a function of the pressure applied to the conductor. Hence, by inserting a previously calibrated coil in a pressure vessel and determining its resistance, a measure of the interior pressure is obtained. Unfortunately, most substances have a temperature coefficient of resistance as well as a pressure coefficient. To be certain that the two effects are not confused, it is customary to select a substance with a negligibly small temperature coefficient at some convenient temperature. Then, by operating at that temperature, changes in resistance can be assigned to the pressure surrounding the conductor. Such gauges commonly employ alloys of manganin or gold-chromium, since these materials have sufficiently large pressure coefficients of resistance, while their resistance is relatively insensitive to temperature changes in the ambient range. In particular, manganin has been used for pressures from 20,000 lb to at least 400,000 lb per square inch. The resistance is usually measured with a bridge circuit.

Several aspects of manganin gauges have been investigated by previous experimenters. These

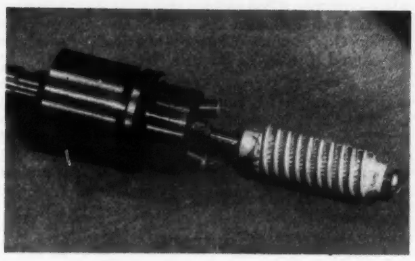


Fig. 8—Insulating plug used as holder for a pressure-sensitive resistance coil

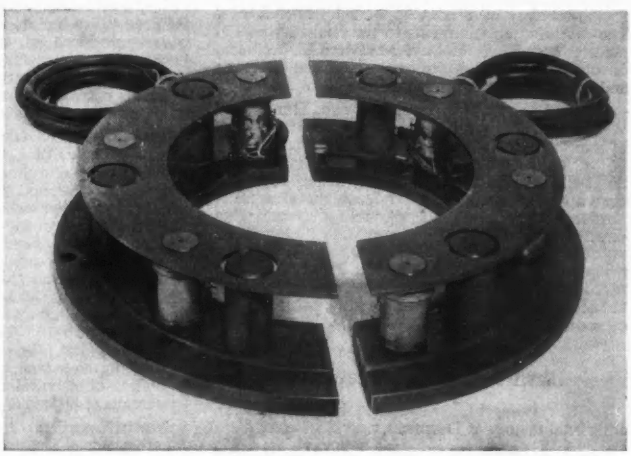
studies indicated that additional work was called for, particularly on the method of mounting and supporting the wire in the pressure fluid. The evidence indicated that reduction of mechanical strain in the resistance wire would result in greater stability and more nearly linear relation between coil resistance and pressure. This is strikingly similar to the problem of mounting and supporting the platinum wire in resistance thermometry. There were some differences of opinion on the most desirable techniques for pressure and temperature seasoning of the completed gauge, and some questions to be resolved regarding the influence of ageing and the effect of various bridge techniques on accuracy. Before any of these items were investigated, a closure plug was devised through which four leads—two from each terminal of the resistance coil—could be brought out from the pressure vessel, as illustrated in Fig. 8. Commercially available gauges are ordinarily constructed so that one end of the wire coil is grounded to the interior of the vessel while the other end is brought outside through an insulated lead. In observing the resistance changes of the wire in such a gauge, parts of the electrical lead wires as well as parts of the other equipment must be included in the electrical circuit of the bridge. Such a system has the disadvantage that changes in the electrical resistance of these external elements may well mask small changes in the resistance of the pressure coil itself.

Several of these closure plugs were constructed and various resistance wire gauges were attached. A study of manganin wire coils led to the devising of a configuration which gives a substantial improvement in the resistance stability and the linearity of the pressure-resistance characteristic. Data were taken on the effect of heat treatment on gold-chromium, and its pressure coefficient was determined to 20,000 lb per square inch. Utilising the ice-VI-liquid transition line as a reference pressure, several manganin wire gauges were compared. Further work along these lines is continuing, but much more will be possible when a primary standard of pressure to 200,000 lb per square inch is obtained.

Electrical Load Measuring System for Kingsbury Thrust Bearings

To facilitate the continuous supervision of thrust loads on the shafts of steam turbines, an electrical load measuring system for Kingsbury thrust bearings was developed recently by the Electronics and Instrumentation Division of the Baldwin-Lima-Hamilton Corporation, Cambridge, Massachusetts. Thrust is measured by means of resistance wire strain gauges incorporated in a special thrust element, which is shown in the accompanying illustration. The element is installed as part of the Kingsbury bearing, with the output being recorded on a Baldwin strip chart recorder. An alarm circuit is provided also to warn of overloads in either direction on the shaft. The first use of the equipment is in automatic supervisory systems for Westinghouse steam turbines. Such equipment has become necessary with the increase in the size, temperatures, pressures and complexity of such turbines.

The thrust load sensing equipment consists of two two-segment units—one for either direction of thrust—against which the thrust loads are exerted when installed in the Kingsbury bearing. Six gauged columns mounted between two annular rings are spaced 60 deg. apart around the shaft, as illustrated, and are sealed to protect the strain-sensitive elements from the lubricating oil in the bearing. The thrust elements are segmented to permit an easy installation around the shaft. Overload protection is provided by steel dummy columns alongside each gauged column. These columns would take any compression load that depressed the gauged columns more than 0·02in. The thrust units were designed for a 100,000 lb load. The accuracy of thrust load measurement is within 3 per cent, which is well within the builder's requirement of 5 per cent. The recorder response to load changes is 0·5 second for full scale.



Resistance wire strain gauge thrust element for measuring thrust loads on steam turbine shafts

Loan of Plutonium-Beryllium Neutron Sources to Educational Institutions

The U.S. Atomic Energy Commission recently announced that it will make available plutonium-beryllium neutron sources for sub-critical assemblies used by non-profit American educational institutions engaged in training and research work in the nuclear sciences. The recipients of plutonium-beryllium neutron sources will be required to obtain a licence to possess the special nuclear material. The plutonium-beryllium neutron sources possess the advantage of long life. The negligible daily radioactive decay of a plutonium-beryllium neutron source eliminates the necessity of frequent calibrations of neutron source strength which are necessary when using neutron sources which decay rapidly.

Personal and Business

Appointments

SHARPLES CENTRIFUGES, Ltd., Woodchester, Stroud, announces the appointment of Mr. F. A. Cullum as marine sales manager.

MR. C. R. KING has been appointed chairman of the National Inspection Council for Electrical Installation Contracting, in succession to the late Mr. P. V. Hunter.

THE HYMATIC ENGINEERING COMPANY, Ltd., Redditch, Worcs, has announced the appointment of Mr. J. H. Hutchinson, A.M.I.Mech.E., as assistant engineering sales manager.

MR. S. R. EADE, M.I.E.E., has been appointed sole managing director, and Mr. J. Clement, sales director, of A.E.I. Lamp and Lighting Company, Ltd., Crown House, Aldwych, London, W.C.2.

MR. G. T. SHOOSMITH, M.I.C.E., M.I.Mech.E., has been appointed chairman and managing director, and Mr. M. A. H. Walford, A.M.I.Mech.E., deputy managing director, of Plenty and Son, Ltd., Newbury, Berks.

MR. E. P. JONES has been appointed secretary of Hackbridge and Hewittic Electric Company, Ltd., Walton-on-Thames, Surrey. He succeeds Mr. J. S. Dryden, who has retired after thirty-six years in the company's service.

MR. S. W. HYDE has been appointed works manager at the Fraser and Chalmers Engineering Works, Erith, of The General Electric Company, Ltd. He succeeds Mr. J. E. Forster, who has retired after thirty-one years in the company's service.

MR. C. F. WELLS, M.I.Mech.E., has been appointed manager of the gear engineering department of the British Thomson-Houston Company, Ltd. He succeeds Mr. S. A. Couling, M.I.Mech.E., who is now devoting his full time to the company's special production problems.

THE FAIREY AVIATION COMPANY, Ltd., Hayes, Middlesex, states that Mr. G. W. Hall and Mr. Richard Fairey have been appointed vice-chairmen. The following appointments to the board have been made: Mr. R. L. Lickley, M.I.Mech.E., technical director; Mr. J. C. Macpherson, financial director; and Mr. Alan Vines, production director.

Mr. J. HUNTER, a director of Swan, Hunter and Wigham Richardson, Ltd., has been elected president of the Shipbuilding Employers' Federation, and Mr. G. C. Parker, managing director of the Caledon Shipbuilding and Engineering Company, Ltd., has been appointed senior vice-president, the other vice-presidents being Mr. R. W. Johnson, managing director of Cammell Laird and Co. (Shipbuilders and Engineers), Ltd., and Mr. G. H. R. Towers, managing director of John Redhead and Sons, Ltd. Mr. J. Tocher has been elected chairman of the Conference and Works Board, and Mr. G. Morrison has been made vice-chairman.

Business Announcements

JOY-SULLIVAN, Ltd., Greenock, has acquired an additional factory at Dronfield, near Sheffield.

LORD BRIDGEMAN, chairman of Atlas Copco (Great Britain), Ltd., is on a visit to South Africa.

HEYES AND CO., Ltd., Water-Heyes Works, Wigan, has opened a Scottish sales depot at 158, Bath Street, Glasgow, C.2.

DE HAVILLAND HOLDINGS, Ltd., Hatfield, Herts, has acquired an interest in Saunders-Roe, Ltd., East Cowes, Isle of Wight.

THE MACHINE TOOL TRADES ASSOCIATION has moved to Brettenham House, Lancaster Place, W.C.2 (telephone, Temple Bar 3606).

LANCASHIRE DYNAMO HOLDINGS, Ltd., has announced proposals for acquiring the business of J. G. Statter and Co., Ltd., Amersham Common, Bucks.

ROBERT JENKINS AND CO., Ltd., has added a new shop, 220ft long by 89ft wide, to its Rotherham works, for the manufacture of heavy pressure vessels to Class 1 specifications.

EXPANDITE, Ltd., Chase Road, London, N.W.10, states that it is now manufacturing in this country "Barra" concrete additives manufactured by Meynadier et Cie., Switzerland.

THE THERMOTANK GROUP announces the formation of a new company entitled Sound Control, Ltd. It will deal with all aspects of architectural acoustics. The company is operating from Colneside Works, West Drayton, Middlesex, and Mr. D. G. Smart is the managing director.

ASSOCIATED CEMENT COMPANIES, Ltd. (of Bombay), Vickers, Ltd., and Babcock and Wilcox, Ltd., have announced the formation of a company entitled Acc-Vickers-Babcock (Private), Ltd. This new company plans to build a heavy engineering works in the vicinity of Durgapur, West Bengal.

THE BRUSH GROUP, Ltd., has announced a re-organisation of its heavy marine engine business. As a consequence, it has formed two separate companies to deal with this business. They are: Associated British Oil Engines Marine (Mirrlees), Ltd., and Associated British Oil Engines (National), Ltd.

METALOCK (CEYLON), Ltd., has been formed to deal with castings repairs in Ceylon. Dr. H. C. P. Gunewardene, of Bonars (Ceylon), Ltd., has been appointed managing director, the other directors being Major E. C. Peckham, chairman of Metalock (Britain), Ltd.; and Mr. David Arvidsson, president of the Metalock International Association.

Contracts

FOLLAND AIRCRAFT, Ltd., Hamble, Southampton, is to supply a number of "Gnat" light fighters to the Finnish Air Force. Delivery will commence in 1957.

BRITISH TRANSPORT WATERWAYS announces that a contract has been placed with the Yorkshire Hennebique Contracting Company, Ltd., York, for the construction of the new lock to be built at Long Sandall, on the Sheffield and South Yorkshire Navigation. The new lock will be double chambered, 22ft wide, with an overall length of 215ft. By accommodating craft carrying up to 250 tons (the present limit is 90 tons), it will remove a "bottleneck" between Goole and Doncaster. The total cost of the work will be over £100,000.

Miscellanea

WORK OF THE U.S. ATOMIC ENERGY COMMISSION.—On page 493 of our issue of October 5th, photographs were reproduced of the 1825kW capacity Army Package Power Reactor and of a 50kW homogeneous solution reactor constructed by Atomics International. Readers should note that the captions relating to these two engravings were transposed.

CONFERENCE ON TECHNICAL ILLUSTRATION.—The City and Guilds of London Institute has agreed to add the subject of technical illustration to its examination list. From next year it will offer intermediate and final examinations in the subject. To give an opportunity to principals of Colleges of Art, and to their staffs, to discuss the scheme with members of the advisory committee who drafted it, a conference is to be held on Thursday and Friday, November 29th and 30th, at the L.C.C. Central School of Arts and Crafts, Southampton Row, London, W.C.1. The conference will begin on November 29th at 2.30 p.m., and the second session will be at 10 a.m. on the morning of November 30th. A small exhibition of technical artists' work is included in the conference programme.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS.—The twenty-first Parsons Memorial Lecture was given by Vice-Admiral Sir Frank T. Mason, K.C.B., Engineer-in-Chief of the Fleet, on November 2nd, before the North East Coast Institution of Engineers and Shipbuilders. The lecture was entitled "A Review of Naval Propulsion Engineering Progress in the Last Ten Years." Sir Frank recalled that the end of the war in 1945 marked the start of a period of intensive research and development in the fields of steam turbines, diesel engines, and gas turbines for naval propulsion. This had continued through the period and the fruits of this development work were now at sea in new classes of ships, which had recently joined the Fleet. At the same time, the development of new types of weapons had resulted in great changes in the military characteristics of ships and this in turn had led to a further review of the requirements of propulsion machinery. The lecture outlined three phases of machinery development; that based on analysis of the lessons of World War II and using engineering achievements up to 1950; that needed for ships influenced by new armament and the possibility of nuclear attack, and using engineering achievements up to 1955, and the final phase resulting from the possibility of using nuclear energy for propulsion. The general principles and the Admiralty establishments involved in the development and testing work were outlined, and the types of machinery evolved described briefly. The first phase resulted in steam turbine, diesel and gas turbine machinery developed along more or less conventional lines. The steam installations had been taken to a point where further development was subject to the law of diminishing returns for rapidly increasing effort. Diesel development had resulted in the Admiralty Standard Range of engines and the very lightweight "Deltic" engine for small craft. The Admiralty developments in gas turbines had resulted in several interesting engines of differing characteristics. These, Sir Frank said, had given rise to conclusions on the type of gas turbine appropriate to naval use. These installations were briefly described and a fuller account of the development of each component was given in an appendix. The second phase demanded further reduction in the weight of machinery and fuel and also in the height of machinery spaces. This resulted in the adoption of steam turbine machinery for a proportion of full power with gas turbines geared to the same shaft to give the higher powers. The advantages of this type of machinery to meet nuclear warfare were mentioned. The possibilities of nuclear propulsion were briefly mentioned and the lecturer commented on the lessons learned by the Admiralty in this period of development, the need for careful planning, and the need for manufacturing excellence.

INTERNATIONAL EXCHANGES OF STUDENTS.—The International Association for the Exchange of Students for Technical Experience has published its ninth annual report. It records that during the current year 5711 students from twenty-two member countries have participated in the exchange schemes. To make these exchanges effective, the Association has had the co-operation of 2496 industrial organisations and 374 universities and technical colleges. It is interesting to note that when the Association began its work in 1948, there were ten member countries and the number of student exchanges was 920. During the summer vacation this year, Great Britain received 774 students. Among that number, there were thirty-six who are gaining experience in chemical engineering, forty-four in civil engineering, 151 in electrical engineering, 169 in mechanical engineering, two in industrial engineering, eighteen in metallurgy, eighty-one in mining, and three in shipbuilding. In this country, there are now thirty-four universities and colleges affiliated to the Association, and this year 743 students from them have been sent to other countries. The report pays tribute to the work of Mr. J. Newby, of the Imperial College of Science and Technology, London, who has served as general secretary since the formation of the Association in 1948. Mr. Newby has now retired from that office, but continues as secretary for the Association's activities in this country.

Launches and Trial Trips

VOLVULA, oil tanker; built at the Wallsend yard of Swan, Hunter and Wigham Richardson, Ltd., for Shell Tankers, Ltd.; length overall 659ft 11in, length between perpendiculars 635ft, breadth moulded 84ft 3in, depth moulded 46ft 3in, load draught 34ft 8¼in, deadweight 32,040 tons, service speed 16 knots; thirty cargo oil tanks, one main cargo pump room, four 1160 tons per hour turbine-driven, vertical, centrifugal cargo pumps, three stripping pumps; two 550kW, 450V turbine-driven alternators, one 150kW diesel-driven alternator; one set of double reduction geared turbines built by Wallsend Slipway and Engineering Company, Ltd., 14,500 s.h.p. at 109 propeller r.p.m., steam supplied at 600 lb per square inch and 850 deg. Fah. by two Babcock and Wilcox integral furnace boilers. Trial, October 3rd.

BADAGRY PALM, cargo liner; built at the Neptune Works of Swan, Hunter and Wigham Richardson, Ltd., for the Palm Line, Ltd.; length between perpendiculars 415ft, breadth moulded 58ft, depth moulded to shelter deck 35ft; trial speed 15 knots; five cargo holds, one 75-ton, six 10-ton and ten 5-ton derricks, electric winches, three 250kW diesel-driven generators, one 30kW diesel-driven emergency generator; Swan Hunter-Doxford diaphragm oil engine, four cylinders, 670mm diameter by 2320mm combined stroke, 4500 b.h.p. at 118 r.p.m. Trial, October 9th.

FORT CAROLINE, banana carrier; built by the Chantiers de Provence, for the Compagnie Generale Transatlantique; length overall 377ft 4in, length between perpendiculars 346ft 1½in, breadth moulded 51ft 10in, depth moulded to upper deck 36ft 1in, draught loaded 21ft 4in, deadweight 2500 tons, displacement 6540 tons, speed 17 knots at 5900 tons displacement; twelve passengers; six watertight compartments, two continuous decks, four holds Bipod masts, eight 3-ton derricks, electric winches, three 250kW diesel-driven generators; Burmeister and Wain Mark 62VTBF diesel engine, 6000 h.p. at 150 r.p.m. Trial, October.

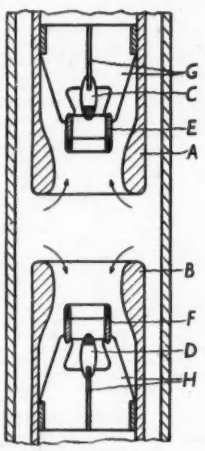
British Patent Specifications

When an invention is communicated from abroad the name and address of the communicator are printed in italics. When an abridgment is not illustrated the specification is without drawings. The date first given is the date of application; the second date, at the end of the abridgment, is the date of publication of the complete specification. Copies of specifications may be obtained at the Patent Office Sales Branch, 15, Southampton Buildings, Chancery Lane, W.C.2, 3s. each.

ELECTRICAL ENGINEERING

758,266. January 26, 1954.—HIGH-VOLTAGE GAS-BLAST ELECTRIC CIRCUIT BREAKER, Licentia Patent-Verwaltungs-G.m.b.H., 31–32, Hohe Bleichen, Hamburg 36, Germany.

According to the invention, a high-voltage gas-blast circuit breaker is characterised in that the hollow contact pin accommodates within its cavity a central arcing electrode and an annular or cylindrical co-axial auxiliary electrode, both electrodes being fastened to the hollow contact pin. In this way a penetration into the hollow contact pin of the electric field set up between the breaker contacts is practically suppressed without impeding substantially the flow of the compressed quenching gas. The drawing shows part of a circuit breaker in which both contacts are formed by hollow contact pins *A* and *B*. The flow of the quenching gas is indicated by arrows. The entry into each hollow contact pin is nozzle-shaped, as shown, and the dimensions may be such that supersonic speeds can be obtained within the nozzles. Each contact pin comprises an arcing electrode *C* or *D* in the axis of the pin and connected conductively and preferably directly, with the associated hollow contact pin. A cylindrical auxiliary electrode *E* or *F* is arranged between the arcing electrode and the contact end of each contact pin. Each auxiliary electrode is connected with the associated arcing electrode *C* or *D*, and is so shaped and dimensioned that it practically prevents a penetration of the electric field beyond the electrode, without substantially impeding the flow of the compressed gas. The arcing electrodes and the auxiliary electrodes are shaped to form streamlined bodies. Each auxiliary electrode and the associated arcing electrode are carried by metallic webs *G* or *H*, which are firmly connected to the hollow contact pin. As shown, the webs which support each auxiliary electrode are arranged an appreciable distance behind the contact end of the pin. The ends of the arcing electrodes and of the auxiliary electrodes are made of a high-melting-point metal.—*October* 3, 1956.

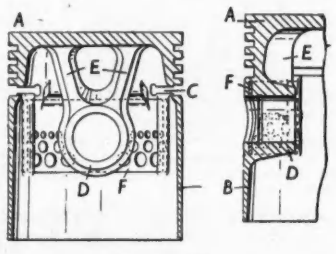


No. 758,266

INTERNAL COMBUSTION ENGINES

759,191. February 4, 1954.—BIMETALLIC LIGHT METAL PISTON, Aluminium Laboratories, Ltd., 1800, Sun Life Building, Montreal, 2, Canada.

The invention relates to pistons made of light metal, such as aluminium and aluminium and magnesium alloys, having a skirt which is partly separated from the piston head by transverse slots or perforations.



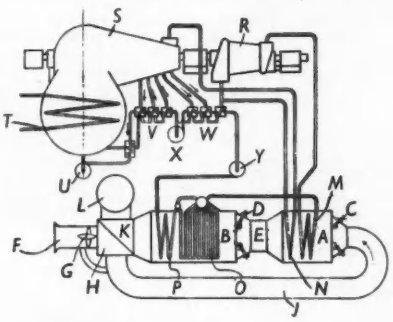
No. 759,191

The object of the invention is to control the effects of thermal expansion at different levels of the skirt by simple means. As will be seen from the drawing, the piston head *A*, which contains annular piston ring grooves, is separated from the piston shank *B* over parts of the periphery by transverse slots *C*. The pin bosses *D* are connected with the bottom of the piston head by stays *E*. On the inside of the skirt *B* are inserts *F*, in the form of sleeve segments, which have a thermal coefficient of expansion which differs from that of the material of the piston, so that the inserts combine with the adjacent parts of the skirt *B* to form bimetallic members. The inserts have apertures for the piston pins. In addition, there are, in the bottom part of the insert, three rows of perforations of different sizes. In this way, the resistance to bending of the insert decreases from the top towards the bottom in a definite manner, which can be controlled as desired by varying the size, the number and the arrangement of the perforations. Although the wall thickness of the piston skirt decreases slightly from the top, the bimetallic effect of the top portion of the insert above the rows of perforations will be greater on the portion of the skirt with which it is in contact than the effect of the lower portion of the insert, in which the perforations are formed. Modified designs of inserts are also shown in the specification. —*October* 17, 1956.

STEAM GENERATORS

759,512. November 6, 1953.—THERMAL POWER PLANT, Metropolitan-Vickers Electrical Company, Ltd., St. Paul's Corner, 1–3, St. Paul's Churchyard, London, E.C.4. (*Inventor: William Eccles.*)

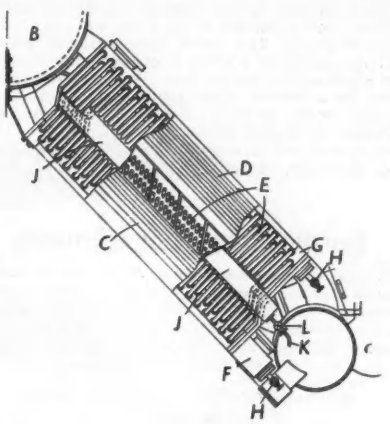
The invention relates to thermal power plant and more particularly to vapour generating plant. According to the invention a vapour generating plant includes a first combustion stage in which fuel is burnt and the vapour is superheated and a later combustion stage in which further fuel is burnt and in which working medium liquid is vaporised, together with means whereby the later combustion stage is fed with combustion gases from the first stage partially cooled by the superheater and heat exchanger means whereby air supply to the first stage is preheated by exhaust gas from the last stage after they have passed through vapour generating plant for the working medium. In some cases, a further combustion stage or stages may be added—for instance, the superheating may be carried out in two stages or the superheating may be partially done in the second stage of combustion. In the drawing, *A* is the first combustion chamber and *B* the second combustion chamber. These are provided with burners *C* and *D* respectively and communicate with each other through a gas passage *E*. Air for combustion is drawn in through an intake *F* by a fan *G*, from whence it passes through the cold passages of a heat exchanger *H* and ducting *J* to the first combustion chamber *A*, whence the combustion gases pass through the passage *E* to the second combustion chamber *B* and thence through the hot side *K* of the heat exchanger to the waste heat chimney *L*. As will be seen from the drawing, the first combustion chamber *A* contains a superheater *M* and a steam reheater *N*, whilst the second combustion chamber *B* contains a steam boiler *O* and an economiser *P*. In the arrangement shown the steam plant feeds a two-stage turbine set consisting of a high-pressure steam turbine *R* and a low-pressure turbine *S* provided with a condenser *T*. The working medium in the form of condensate from the condenser is forced by a pump *U* through bled steam heaters *V* and *W* and then by feed pumps *X* and *Y* through the economiser *P*, from whence it passes to the boiler stage *O*. Steam from the boiler stage is superheated in superheater *M* and then passed to the h.p. steam turbine. The exhaust steam from the h.p. steam turbine *R* is passed through the steam reheater *N* and thence to the l.p. steam turbine. The application of the invention to a mercury and steam plant operating in a binary cycle is also shown in the specification. —*October* 17, 1956.



No. 759,512

759,471.—May 3, 1950.—STEAM SUPERHEATERS FOR MARINE AND LIKE WATER-TUBE BOILERS, The Superheater Company, Ltd., and Harold Melhuish, both of 53, Haymarket, London, S.W.1.

The invention relates to steam superheaters of the kind in which the superheating elements are disposed with their tubes substantially horizontal in a space between banks of water tubes connecting a lower or water drum to an upper or steam and water drum of the boiler. Its object is to provide improved means for use in connecting to each other the respective portions of steam superheater elements, which, in addition to providing a simple and efficient connection which can be readily made and broken when requisite, will facilitate draining the elements, and not impede manipulation of the portions of the elements when placing them in, or removing them from, the boiler. Referring to the drawing, the boiler shown comprises a lower water drum *A* and an upper steam and water drum *B*, these drums being connected by banks *C* and *D* of generating tubes. Between the tube banks superheater elements *E* are disposed, *F*, *G* being the superheater headers which are equipped with the usual drain valves *H*. Each superheater element *E* is formed of two U-shaped portions joined by a connecting bar *J* to which the appropriate ends of the portions are attached, the respective tube ends of an element being connected to passages in the bar and communicating with one another through the passage. The passages in the bar lead into a duct extending longitudinally of the bar, closed at its upper end, and the duct, or the lowermost of the ducts, being equipped at its lower end with a drain connection *K* controlled by a valve *L*. Details of the connecting bar and its design are also shown in the specification. —*October* 17, 1956.

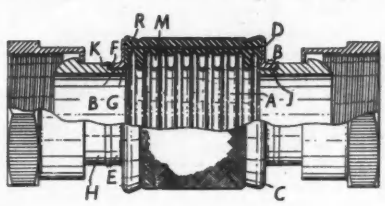


No. 759,471

TUBE AND PIPE COUPLINGS

759,306. May 14, 1954.—FLEXIBLE METAL PIPE AND LIKE COUPLINGS, K.A.C., Ltd., Fifth Street, Montrose Avenue, Hillington, Glasgow, S.W.2. (*Inventor: Thomas Gerald Llewhellin.*)

The invention concerns improvements in flexible metal pipe and like couplings, and has particular reference to flexible couplings of the kind comprising a pair of unions fluid tightly connected by a length of corrugated metal tubing. The coupling illustrated in the drawing comprises an annularly corrugated metal bellows *A* having a cylindrical portion *B* at each end of the same internal diameter as the troughs of the corrugations of the bellows. On each of the cylindrical ends is threaded a flange *C* comprising an annular flange disc *D* having a tubular coaxial boss *E*, which is a close fit upon the cylindrical end portion *B*. Each disc is located nearer to the inner end of its boss than to the outer end. The axial length of each boss is smaller than the length of the cylindrical end on to which it is fitted, and after each flange *C* has been applied the corresponding outer marginal portion *F* of the bellows is spun into engagement with the outer end of the boss *E* to retain the flange firmly. The ends of the bellows are preferably spun into the bores of their end flanges *C* so as to be snug fits therein. End unions comprising tubular spigots *H* each of which has its inner end rebated to provide an annular recess *J* for receiving one end of the bellows and the tubular boss of the flange are attached to the bellows, the rebated end of each spigot being pushed tightly into the bellows. The extent to which the spigot can move into the bellows is limited by the engagement of the shoulder *K* against the outspun marginal portion *F* of the bellows. The coupling having been assembled thus far, the tubular spigots,



No. 759,306

the outspun marginal portions of the bellows and the tubular bosses of the flanges are united together by an annular brazed joint. Where rotatably mounted union nuts are to be provided on the spigots *H*, they are, of course, assembled on the spigots before assembly. Fabric *M* is wrapped around the outside of the bellows, leaving the last one or two corrugations uncovered. The fabric extends between the crests *O* of the covered corrugations so that the troughs are closed externally. Rubber or like material which is heat and oil resistant, is moulded over the bellows and the fabric and down into the corrugations and into the annular recesses between the end flanges, as shown, and is bonded to the inside surfaces of the end flanges *C*. The rubber forms a sheath and an annular marginal portion *R* on each disc is spun in to grip and protect the ends. A strip of wire gauze may be embedded in the sheath and, if desired, a braided metal or other covering may be provided around the sheath before flanges are spun. The rubber composition reinforces the bellows and damps out vibrations.—*October* 17, 1956.

Forthcoming Engagements

Secretaries of Institutions, Societies, &c., desirous of having notices of meetings inserted in this column, are requested to note that, in order to make sure of their insertion, the necessary information should reach this office not later than a fortnight before the meeting. In all cases the TIME *and* PLACE *at which the meeting is to be held should be clearly stated.*

ASSOCIATION OF SUPERVISING ELECTRICAL ENGINEERS

Sat., Nov. 17th.—N. LONDON BRANCH: Visit to Park Royal Brewery, Arthur Guinness Son and Co., Ltd., 2.15 p.m.——OXFORD, READING AND DISTRICTS BRANCH: Regents Park College, Pusey Street, Oxford, "The 13th Edition of the I.E.E. Rules," J. J. Looker, 6.30 p.m.

Wed., Nov. 21st.—NOTTINGHAM BRANCH: E. Midlands Electricity Board's Showroom Theatre, Smithy Row, Nottingham, "Rolling Bearings," C. S. Clarke, 7.30 p.m.——SOUTHAMPTON BRANCH: Visit to Police Headquarters, Civic Centre, Southampton, 7.30 p.m.

BRITISH INSTITUTION OF RADIO ENGINEERS

Fri., Nov. 23rd.—SCOTTISH SECTION: Department of Natural Philosophy, The University, Edinburgh, "Information Theory," L. C. Stenning, P. Jones and P. Holroyd, 7 p.m.

Wed., Nov. 28th.—School of Hygiene and Tropical Medicine, Keppel Street, Gower Street, London, W.C.1, "Colour Television," G. N. Patchett, 6.30 p.m.

COMBUSTION ENGINEERING ASSOCIATION

Wed., Nov. 21st.—Talbot Hotel, Oldbury, "The Smokeless Operation of Boilers and Furnaces on Solid Fuel," C. H. G. Hayward, 10.30 a.m., "The Smokeless Operation of Boilers and Furnaces on Liquid Fuel," W. H. Adams, 2.30 p.m.

COVENTRY ENGINEERING SOCIETY

Tues., Nov. 20th.—Room A5, Technical College, Coventry, "What is Mathematics?" T. R. Theakston, 7.30 p.m.

ELECTRICAL ASSOCIATION FOR WOMEN

Wed., Nov. 21st.—Institution of Electrical Engineers, Savoy Place, London, W.C.2, Public meeting organised to discuss points arising from the recent Lighting Campaign, 2.15 p.m.

HULL CHEMICAL AND ENGINEERING SOCIETY

Tues., Nov. 20th.—Church Institute, Hull, "Chemical Crop Protection," A. L. Abel, 7.30 p.m.

ILLUMINATING ENGINEERING SOCIETY

Tues., Nov. 20th.—GLOUCESTER AND CHELTENHAM CENTRE: Fleece Hotel, High Street, Cheltenham, "Road Vehicle Lighting," K. J. Jones, 6.30 p.m.——LIVERPOOL CENTRE: Liverpool Engineering Society, 9, The Temple, 24, Dale Street, Liverpool, "Architects' Views," J. G. R. Sheridan, 6 p.m.

Wed., Nov. 21st.—N. LANCASHIRE GROUP: N.W. Electricity Board, 19, Friargate, Preston, "School Lighting," Part I, "Daylight Considerations," G. S. Pester, "Artificial Light," J. Blackie, 7.15 p.m.

Fri., Nov. 23rd.—BIRMINGHAM CENTRE: Regent House, St. Phillip's Place, Colmore Row, Birmingham, "Modern Applications of Plastics to Lighting Fittings," P. H. Collins, 6 p.m.

Mon., Nov. 26th.—BATH AND BRISTOL CENTRE: Royal Hotel, Bristol, "Lighting for Inspection," H. E. Bellchambers, 7 p.m.

INCORPORATED PLANT ENGINEERS

Wed., Nov. 21st.—KENT BRANCH: Kings Head Hotel, High Street, Rochester, "The Operation and Maintenance of Fuel Economisers," H. J. Gardner and M. R. Wagner, 7 p.m.

Mon., Nov. 26th.—W. AND E. YORKS BRANCH: The University, Leeds, "Electronics in Industry," F. G. Totty, 7.30 p.m.

INSTITUTE OF BRITISH FOUNDRYMEN

Sat., Nov. 17th.—BRISTOL AND WEST OF ENGLAND BRANCH: Grand Hotel, Broad Street, Bristol, 1, "Some Aspects of Modern Casting Design and Running Technique," R. W. Ruddle, 3 p.m.

Tues., Nov. 20th.—E. ANGLIAN SECTION: Public Library, Ipswich, "Some Modern Methods of Pattern-making with particular reference to Pressure Cast Pattern Plates," B. N. S. Perry, 7.30 p.m.

Wed., Nov. 21st.—SOUTHAMPTON SECTION: Technical College, St. Mary Street, Southampton, "Shell Moulding," followed by a film, 7.30 p.m.

INSTITUTE OF MARINE ENGINEERS

Tues., Nov. 20th.—S. WALES SECTION: Institute of Engineers, Park Place, Cardiff, "The Carriage of Edible Oil and Similar Bulk Cargoes," J. Wormald, 7.15 p.m.

Thurs., Nov. 22nd.—W. MIDLANDS SECTION: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Nuclear Engineering," J. A. Kendall, 7 p.m.

Fri., Nov. 23rd.—MERSEYSIDE AND N.W. SECTION: Technical College, Birkenhead, "The Control of Steam Temperature in Marine Watertube Boilers," E. G. Hutchings, 7.15 p.m.

Mon., Nov. 26th.—W. OF ENGLAND SECTION: York House Hotel, George Street, Bath, "Passenger Liner with Engines Aft," R. K. Craig, 7.30 p.m.

INSTITUTE OF METALS

Mon., Nov. 19th.—SHEFFIELD LOCAL SECTION: The University St. George's Square, Sheffield, 1, "Automation," H. D. Turner, 7.30 p.m.

Thurs., Nov. 22nd.—BIRMINGHAM LOCAL SECTION: Exchange and Engineering Centre, Stephenson Place, Birmingham, "Fatigue," N. Thompson, 6.30 p.m.

INSTITUTE OF NAVIGATION

To-day, Nov. 16th.—Royal Geographical Society, 1, Kensington Gore, London, S.W.7, "Navigational Aspects of Turbo-prop Operations over the North Atlantic," J. E. D. Williams, 5.15 p.m.

INSTITUTION OF BRITISH AGRICULTURAL ENGINEERS

Tues., Nov. 20th.—E. MIDLANDS CENTRE: Riseholme Farm Institute, near Lincoln, One-day Conference on Root Crop Machinery, "Irrigation," E. R. Hoare, 10 a.m.——"Modern Methods of Storing Potatoes in Bulk," A. R. Wilson and P. T. G. Twiss, 11.30 a.m.——"Down the Row Thinning," G. L. Maughan, 2 p.m.——"Potato Harvesters," J. C. Hawkins 3.15 p.m.

Mon., Nov. 26th.—W. MIDLANDS CENTRE: Wolseley Engineering, Ltd., Witton, Birmingham, "Modern Equipment for Milk Production," H. S. Hall, 7.30 p.m.

INSTITUTION OF CHEMICAL ENGINEERS

To-day, Nov. 16th.—GRADUATES AND STUDENTS SECTION: Caxton Hall, Westminster, London, S.W.1, "Research and Development in a Chemical-Plant Manufacturing Firm," G. A. Dummett, 6.30 p.m.

Wed., Nov. 21st.—N.W. BRANCH: The University, Leeds, "Non-Newtonian Fluids," E. G. Richardson, 7 p.m.

INSTITUTION OF CIVIL ENGINEERS

Tues., Nov. 20th.—ORDINARY MEETING: Great George Street, Westminster, London, S.W.1, "Allt-na-Lairige Prestressed Concrete Dam," J. A. Banks, 5.30 p.m.

Wed., Nov. 21st.—N.W. ASSOCIATION: 9, The Temple, 24, Dale Street, Liverpool, Chairman's Address, J. A. L. Matheson, 6 p.m.

Thurs. and Fri., Nov. 22nd and 23rd.—BRITISH NUCLEAR ENERGY CONFERENCE: Central Hall, Westminster, London, S.W.1, Symposium of nineteen papers on the Calder Hall Plant, 10 a.m. each day.

INSTITUTION OF ELECTRICAL ENGINEERS

Tues., Nov. 20th.—MEASUREMENT AND CONTROL SECTION: Savoy Place, London, W.C.2, Discussion on "Data Processing Equipment for Experimental Work: A Review of Techniques and Methods," opened by M. V. Wilkes, 5.30 p.m.

Wed., Nov. 21st.—SUPPLY SECTION: Savoy Place, London, W.C.2, Discussion on "Aluminium Conductor Cables," opened by G. F. Peirson, 5.30 p.m.

Thurs., Nov. 22nd.—EDUCATION DISCUSSION CIRCLE: Savoy Place, London, W.C.2, Discussion on "The Presentation and Demonstration of the Theory of Semi-conductors to Students of Electrical Engineering," opened by P. Godfrey, 6 p.m.

INSTITUTION OF ENGINEERING DESIGNERS

Thurs., Nov. 22nd.—38, Portland Place, London, W.1, "Automation and the Designer," Frank G. Woollard, 6.45 p.m.

INSTITUTION OF ENGINEERS AND SHIPBUILDERS IN SCOTLAND

Tues., Nov. 20th.—39, Elmbank Crescent, Glasgow, "Recent Work in the Lithgow Water Tunnel at N.P.L.," A. Silverleaf and L. W. Berry, 6.30 p.m.

INSTITUTION OF HEATING AND VENTILATING ENGINEERS

To-day, Nov. 16th.—MANCHESTER AND DISTRICT BRANCH: Engineers' Club, Albert Square, Manchester, "Water Treatment for Small Steam Boilers," A. J. Rogers, 6.30 p.m.

Tues., Nov. 20th.—LIVERPOOL AND DISTRICT BRANCH: College of Buildings, Clarence Street, Liverpool, "Pipe Sizing Extraordinary," T. H. F. Holman, 6.30 p.m.

Wed., Nov. 21st.—YORKSHIRE BRANCH: Griffin Hotel, Leeds, "High Pressure Hot Water," N. Fincher, 7.30 p.m.

INSTITUTION OF LOCOMOTIVE ENGINEERS

Wed., Nov. 21st.—GENERAL MEETING: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, Symposium on the Training of Locomotive Engineers, "The Training of a Locomotive Engineer," Sir Ronald Nesbitt Hawes, "Engineering Training in the Main Workshops of British Railways," G. F. Parker, "Recruitment and Training of Officers for the Mechanical Engineering and Transportation (Power) Departments of Indian Government Railways," P. G. C. Peyton, 5.30 p.m.

INSTITUTION OF MECHANICAL ENGINEERS

To-day, Nov. 16th.—GENERAL MEETING IN CONJUNCTION WITH THE APPLIED MECHANICS AND LUBRICATION GROUPS: 1, Birdcage Walk, Westminster, London, S.W.1, "Simulated Gear Tooth Contacts: Some Experiments upon their Lubrication and Surface Deformation," A. W. Crook, 6 p.m.

Mon., Nov. 19th.—DERBY A.D. CENTRE: Midland Hotel, Derby, Chairman's Address, A. G. Booth, 7 p.m.——LUTON A.D. CENTRE: George Hotel, Luton, Five papers on Research in Automobile Stability and Control by authors from the Cornell Aeronautical Laboratory, U.S.A., 7 p.m.——SCOTTISH A.D. CENTRE: Institution of Engineers and Shipbuilders, 39, Elmbank Crescent, Glasgow, "Construction and Use of Earth Moving Vehicles," William Rankin, 7.30 p.m.

Tues., Nov. 20th.—EASTERN BRANCH: Technical College, Cambridge, Joint Meeting with the local branch of the Institution of Electrical Engineers, Discussion on Technical Education, 6.30 p.m.

Wed., Nov. 21st.—E. MIDLAND BRANCH: College of Technology and Commerce, Leicester, "Some Experiments on the Deflections and Vibrations of Radial-drilling Machines under Test and Working Conditions," D. F. Galloway, 7.15 p.m.——SOUTHERN BRANCH: Star Hotel, Maidstone, "Financial Management Problems of the Smaller Firms," J. B. Connolly, 7 p.m.——WESTERN BRANCH: University Engineering Laboratories, University Walk, Bristol, "Power Station Auxiliary Plant," Geoffrey F. Kennedy and F. J. Hutchinson, 7 p.m.——N.E. A.D. CENTRE: The University, Leeds, "Rubber Springs for Vehicle Suspension," A. E. Moulton and P. W. Turner, 7.30 p.m.

Thurs. and Fri., Nov. 22nd and 23rd.—BRITISH NUCLEAR ENERGY CONFERENCE: Central Hall, Westminster, London, S.W.1, Calder Hall Symposium, 10 a.m. each day.

INSTITUTION OF NAVAL ARCHITECTS

Tues., Nov. 27th.—Institute of Marine Engineers, 85, Minories, London, E.C.3, "Some Safety Considerations of Nuclear Power Reactors," C. D. Boadle, 5.30 p.m.

INSTITUTION OF POST OFFICE ELECTRICAL ENGINEERS

Wed., Nov. 21st.—INFORMAL MEETING: Conference Room, 4th Floor, Waterloo Bridge House, London, S.E.1, "Some Problems Arising in the Technical Education of P.O. Eng. Staff," F. C. Mead, 5 p.m.

INSTITUTION OF PRODUCTION ENGINEERS

To-day, Nov. 16th.—W. WALES SECTION: Central Library, Alexandra Road, Swansea, "Computer Controlled Machine Tools," M. H. Johnson, 7.30 p.m.——DUNDEE SECTION: Technical College Hall, Bell Street, Dundee, "The Production of the Voith Schneider Propeller with particular reference to its Manufacture," A. Betts Brown, 7.30 p.m.

Mon., Nov. 19th.—COVENTRY SECTION: Craven Arms, High Street, Coventry, "Modern Contour Turning," film and paper, 7 p.m.——N.E. SECTION: Neville Hall, Newcastle upon Tyne, "The Manufacture and Some Applications of Seamless Metallic Tubes," C. Cashmore, 7 p.m.——SHEFFIELD GRADUATE SECTION: Gummers, Ltd., Rotherham, "Corrosion Prevention," Maxwell Lewis, 6.30 p.m.

Tues., Nov. 20th.—LONDON GRADUATE SECTION: 10, Chesterfield Street, London, W.1, "Induction, Resistance and Electro-Gas Heating for Soldering and Brazing," C. Eadon-Clarke, 7.15 p.m.——HALIFAX SECTION: George Hotel, Huddersfield, "Recent Developments in High Production Foundries," J. D. Berry, 7.15 p.m.

Wed., Nov. 21st.—NORWICH SECTION: Assembly House, Norwich, "Aspects of Practical Training for Sandwich Courses," V. Crowther, 7.30 p.m.——BIRMINGHAM SECTION: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Use of Isotopes in Industry," H. Seligman, 7 p.m.——WOLVERHAMPTON GRADUATE SECTION: Technical College, Wulfruna Street, Wolverhampton, "Designing for Production," G. S. Rowland, 7.30 p.m.——DERBY SECTION: Trongates Hotel, Trongate, Derby, "Drop Forgings in Alloy Steels," E. H. Henderson, 7 p.m.

Thurs., Nov. 22nd.—GLOUCESTER SECTION: Cheltenham Motor Club, Priory Lawn, Cheltenham, "Modern Methods of Watch Production," R. A. Fell, 7.45 p.m.——SOUTHERN SECTION: Polygon Hotel, Southampton, "Production of Agricultural Implements," D. M. Macdonell, 7.15 p.m.——N. IRELAND SECTION: Kensington Hotel, College Square East, Belfast, "Incentive Schemes for Maintenance," C. W. Williamson, 7.30 p.m.

Fri., Nov. 23rd.—S. WALES BRANCH: Institute of Engineers, Park Place, Cardiff, "The Training of Production Engineers," V. A. J. Chapman, 7 p.m.

INSTITUTION OF STRUCTURAL ENGINEERS

Tues., Nov. 20th.—MIDLAND COUNTIES BRANCH: Becket Sale Room, Becket Street, Derby, "The Design and Construction of a 90ft Span Prestressed Precast Concrete Roof System," D. D. Matthews, 6.30 p.m.

Wed., Nov. 21st.—YORKSHIRE BRANCH: Central Electricity Authority Offices, Leeds, "Examples of Drift Tunnelling and Prestressing in the Coal Industry," H. C. Griffiths, 6.30 p.m.

Thurs., Nov. 22nd.—11, Upper Belgrave Street, London, S.W.1, "The Design and Construction of the Prestressed Concrete Hangars at Helsinki Airport, Finland," F. W. Gifford and Matti Janhunen, 6 p.m.——LANCASHIRE AND CHESHIRE BRANCH: College of Technology, Manchester, "The Design and Construction of a 90ft Span Prestressed Precast Concrete Roof System," D. D. Matthews, 6.30 p.m.——SCOTTISH BRANCH: Adelphi Hotel, Edinburgh, "Recent Trends and Possible Future Developments in the Design of Gantries and their Overhead Travelling Cranes," P. M. Worthington, 6.15 p.m.

Fri., Nov. 23rd.—MIDLAND COUNTIES BRANCH: James Watt Memorial Institute, Great Charles Street, Birmingham, "The Design, Manufacture and Full Scale Test on Formed Structural Sections," E. Griffin and J. M. Harvey, 6 p.m.

INSTITUTION OF WATER ENGINEERS

Mon., Nov. 19th.—S.E. SECTION: Institution of Civil Engineers, Great George Street, Westminster, London, S.W.1, "Frozen Plumbing," A Symposium on the Cause, Extent and Means of Abolishing an old English Custom, speakers: P. Porteous, W. C. Knill, and D. Dex Harrison, 2.30 p.m.

JUNIOR INSTITUTION OF ENGINEERS

To-day, Nov. 16th.—INFORMAL MEETING: Pepys House, 14, Rochester Row, London, S.W.1, "Semi-Conductors and their Applications," R. A. Hill, 7 p.m.

Fri., Nov. 23rd.—INFORMAL MEETING: Pepys House, 14, Rochester Row, Westminster, London, S.W.1, "Production of Flat Surfaces on Lapmaster Flat Lapping Machines," L. P. Hulin, 7 p.m.

MANCHESTER ASSOCIATION OF ENGINEERS

Fri., Nov. 23rd.—Engineers' Club, Albert Square, Manchester, "Computers in Industry," B. Pollard, 6.45 p.m.

NORTH EAST COAST INSTITUTION OF ENGINEERS AND SHIPBUILDERS

To-day, Nov. 16th.—Mining Institute, Newcastle upon Tyne, "Some Safety Considerations of Nuclear Power Reactors," C. D. Boadle, 6.15 p.m.

Wed., Nov. 21st.—STUDENT SECTION: Bolbec Hall, Newcastle upon Tyne, "The Marine Thrust Bearing," P. A. Milne, 6.45 p.m.

ROYAL AERONAUTICAL SOCIETY

Tues., Nov. 20th.—SECTION LECTURE: 4, Hamilton Place, London, W.1, "C. of A. Flight Testing," D. P. Davies, 7 p.m.

Thurs., Nov. 22nd.—TWELFTH BRITISH COMMONWEALTH AND EMPIRE LECTURE: Institution of Mechanical Engineers, 1, Birdcage Walk, London, S.W.1, "Aeronautical Development in Australia and its Potential Value to the British Commonwealth," L. P. Coombes, 6 p.m.

Fri., Nov. 23rd.—GRADUATES AND STUDENTS SECTION: 4, Hamilton Place, London, W.1, "The Effects of Kinetic Heating on Aircraft Structures," A. W. Kitchenside, 7.30 p.m.

ROYAL SOCIETY OF ARTS

Mon., Nov. 26th, Dec. 3rd and 10th.—THREE CANTOR LECTURES: John Adam Street, Adelphi, London, W.C.2, "Engineering Electronics," L. E. C. Hughes, 6 p.m.

SOCIETY OF INDUSTRIAL RADIOLOGY

To-day, Nov. 16th.—British Institute of Radiology, 32, Welbeck Street, London, W.1, Joint Meeting with the Society of X-Ray Technologists, 7 p.m.

SOCIETY OF INSTRUMENT TECHNOLOGY

Tues., Nov. 27th.—MAIN MEETING: Manson House, Portland Place, London, W.1, "Television Technique Applied to Observation and Control," J. D. McGee, 6.30 p.m.

Advanced Engineering Courses

New Developments in Training. THE POLYTECHNIC, 309, Regent Street, London, W.1. Five lectures weekly, starting Jan. 10th.

Commercial and Industrial Forecasting. THE POLYTECHNIC, 309, Regent Street, London, W.1. Twelve meetings of three hours each, starting Jan. 21st. Fee £1 11s.